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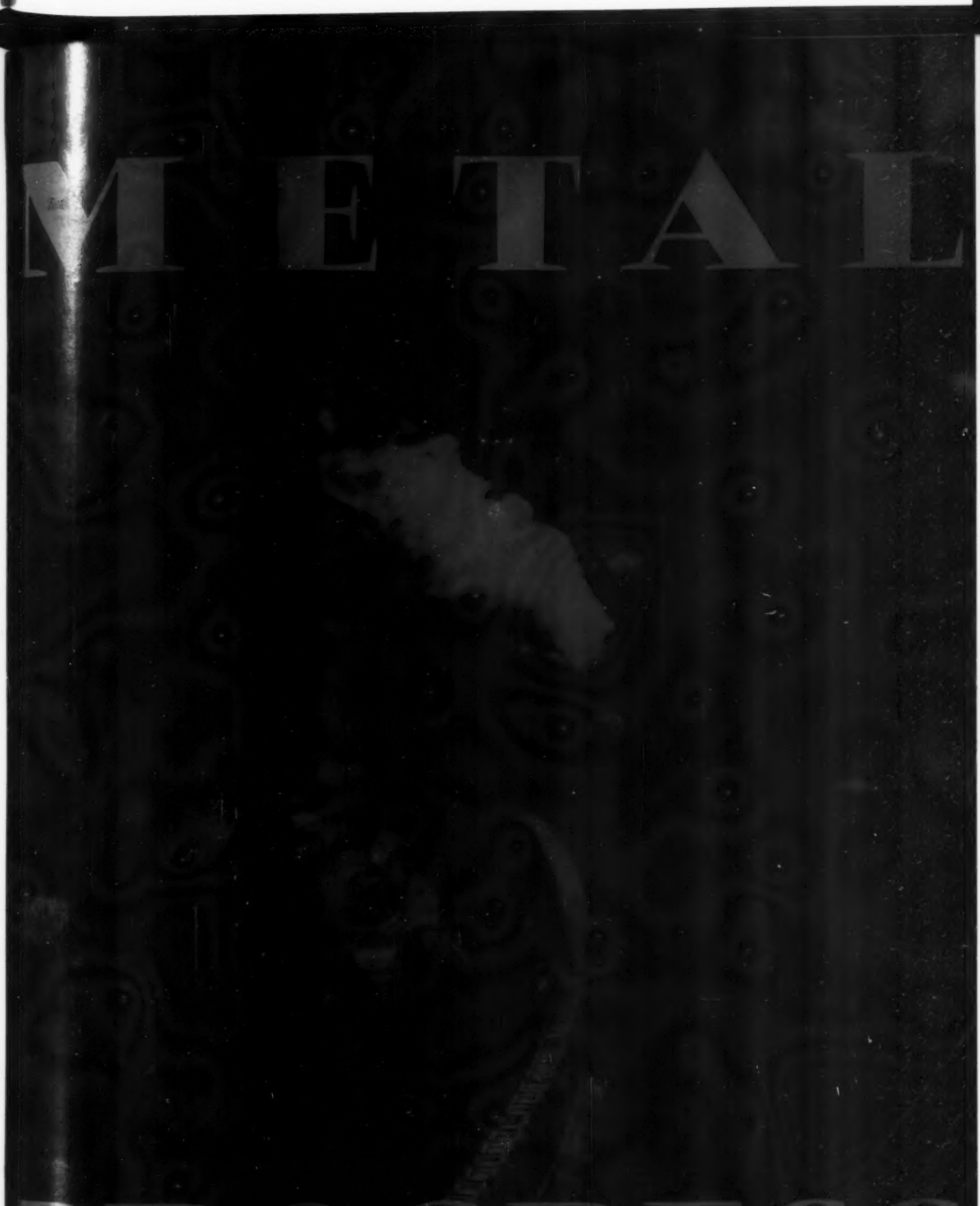

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OCTOBER 1932

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Metal Progress

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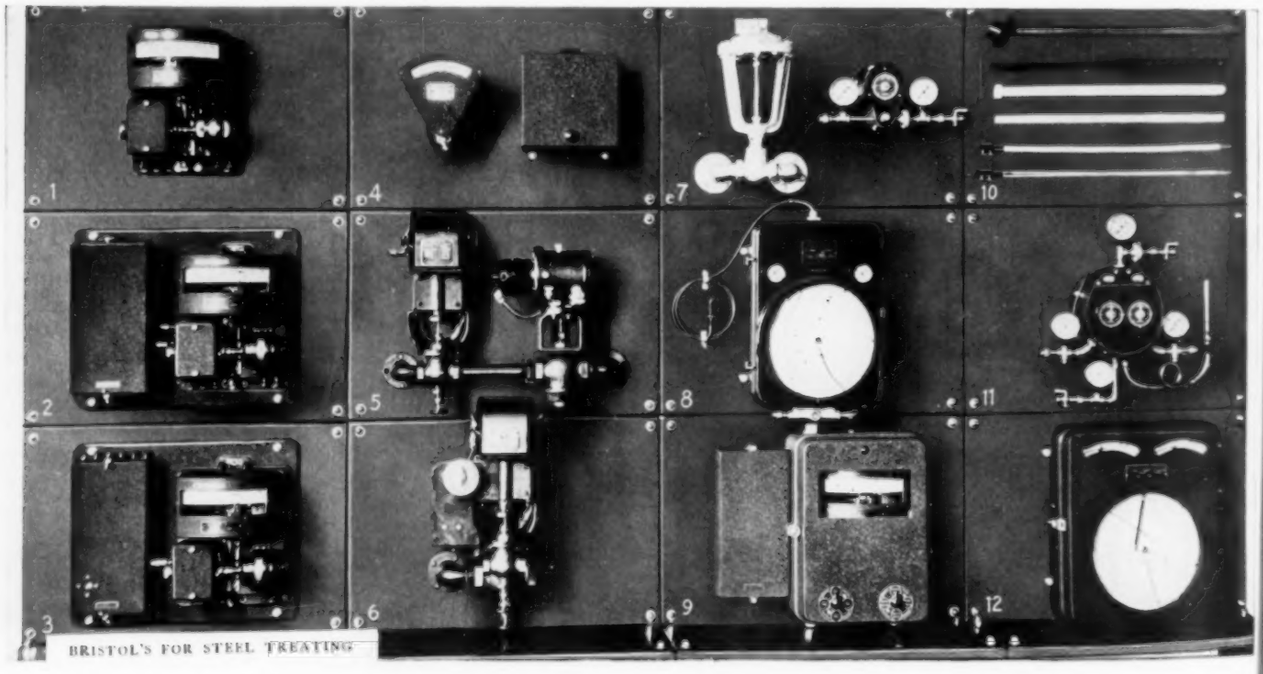

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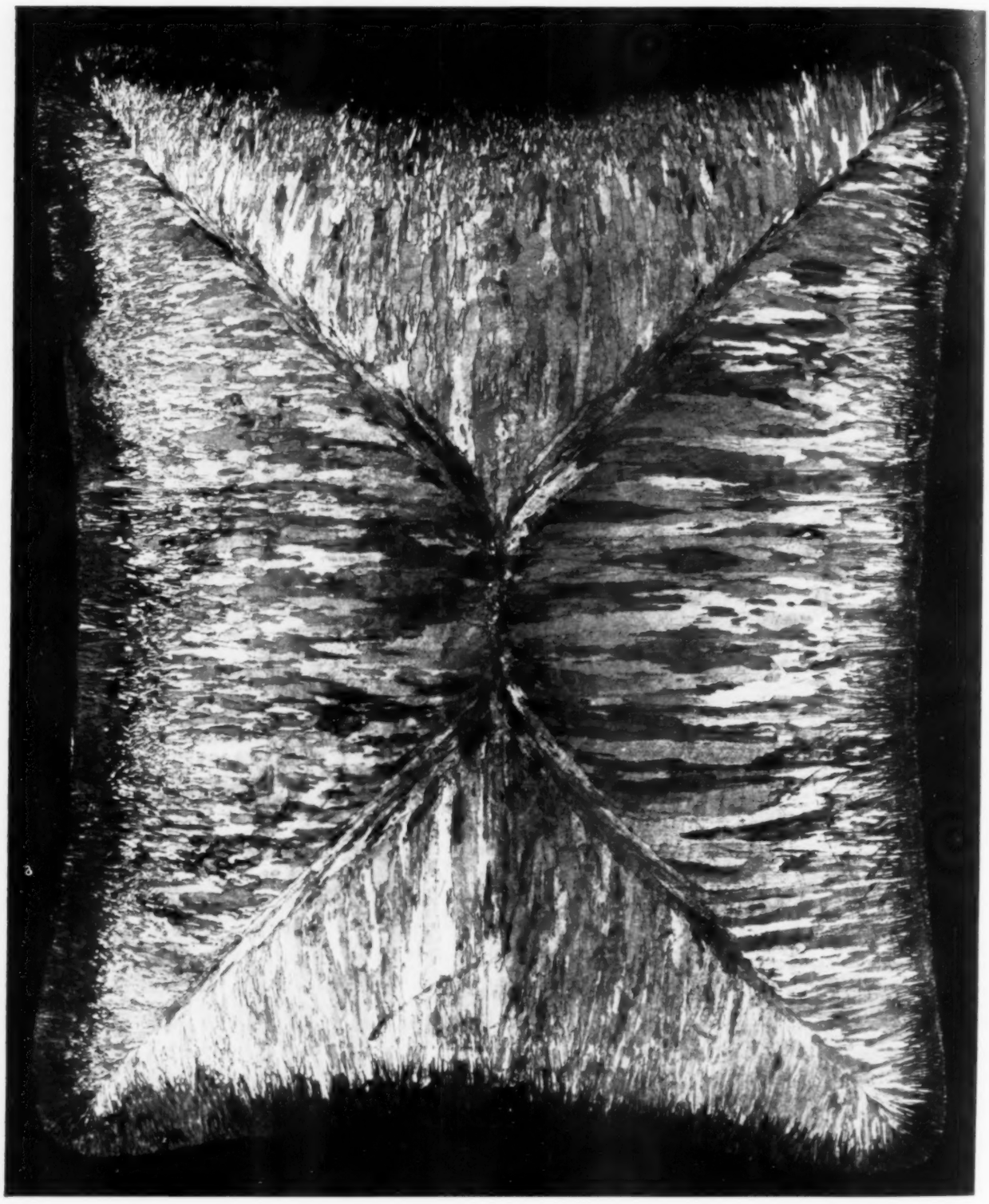


Columnar Crystalline Growth in 17x20-In. Ingot of 18-8 Steel Requires Slow and Careful Reduction to Billet Size

By E. R. Johnson
and R. Sergeson
Metallurgical Dept.
Republic Steel Corp.

a specialized Mill Practice for the stainless steels

Abstract of a paper for Buffalo Convention, A.S.S.T., October, 1932. Written discussion invited

IN THIS PAPER, which was prepared for discussion at the forthcoming Buffalo Convention, A.S.S.T., the authors endeavor to describe the practices within the Central Alloy District of their own organization, especially for manufacturing sheet and strip. In order to keep this abstract within bounds, the portion relating to melting is very much abbreviated.

The term "stainless steels" includes the whole range of alloys, cutlery, low carbon analyses, and complex heat resisting types. For simplicity they may be placed in four groups, each having varying carbon contents:

Group 1, Low chromium (10 to 14%).

Group 2, Medium chromium (16 to 30%).

Group 3, Chrome-nickel (18-8).

Group 4, Chrome-nickel plus other alloy additions.

These alloys are applicable to definite needs; depending on conditions the groups noted will be satisfactory to resist the following types of attack: (*A*) Atmospheric corrosion, groups 1, 2, and 3; (*B*) Immersion or liquid corrosion, groups 2 and 3; and (*C*) Scaling at elevated temperatures, groups 2, 3, and 4.

Electric furnaces are necessary to melt the easily oxidizable metal chromium. Arc furnaces of the Heroult type are usual. Selected scrap, with nickel if required, is melted, the slag removed, a non-oxidizing slag made up (lime-silica for basic furnaces, silica for acid). Preheated ferrochrome is then added in two or three charges. When this is melted ferrosilicon and ferromanganese are added and the temperature adjusted carefully for teeming.

Induction furnaces, such as the Kjellin type, where a circular ring of molten metal forms the secondary of a single-phase transformer, are also in use. Some of the metal in each heat is retained to carry the current at starting. Our furnace operates at 800 kw. at 857 cycles. Natural gas forms a reducing atmosphere. 9000 lb. is tapped every 3 hr.; a month's production figures slightly more than 1 ton per hr. Over 1000 heats have been cast from the same hearth, made from fused magnesite rammed with pitch.

The well-known high frequency induction furnace is also popular. Furnace capacities were originally small, but now one producer owns a 4-ton furnace.

Either type of induction furnace is ideal for melting stainless scrap. Any of the stainless steels can be made in them, and it is believed that the 18-8 alloy from an induction furnace shows different characteristics.

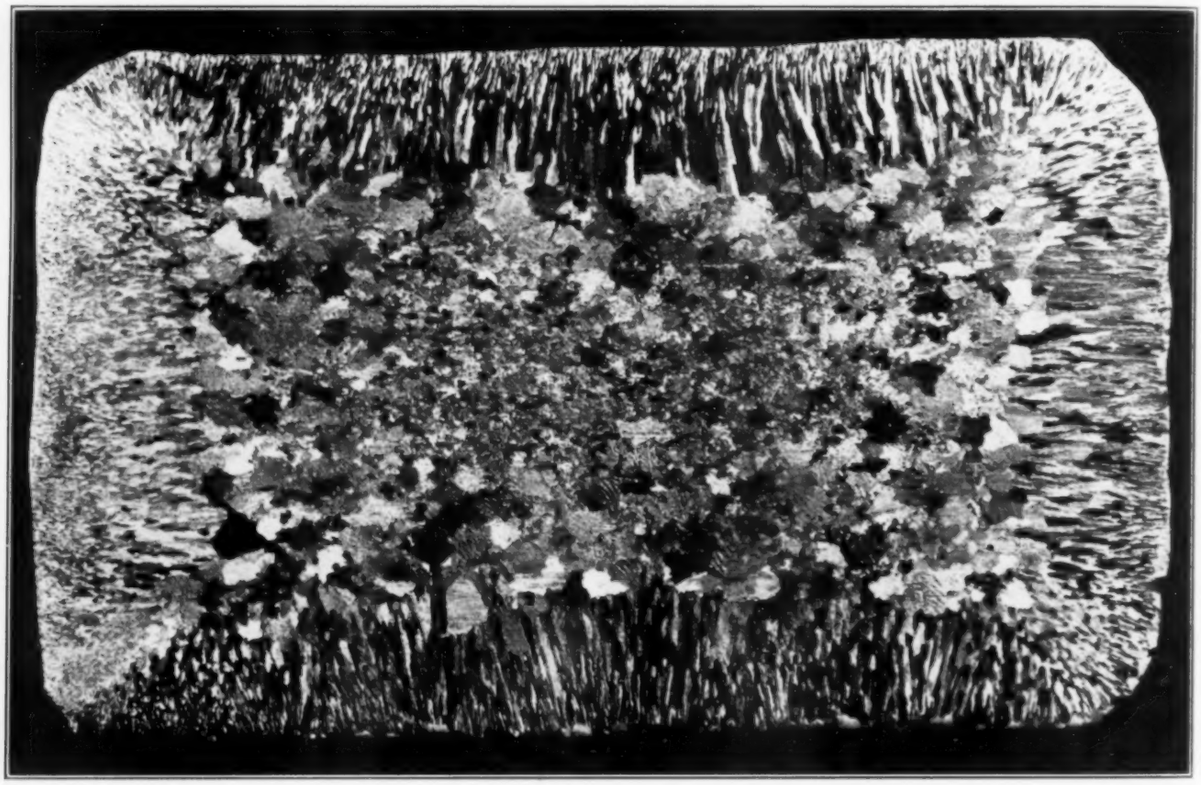
Another method having several modifications can be used: These reduce chrome ore by ferrosilicon, or oxidize the carbon from high carbon ferrochrome.

Ingot weights are generally below 5000 lb. A 20-in. fluted round will be suitable for bars and piercing tube rounds, and a 17x20-in. rec-

tangular ingot for slabs or flat products. Groups 1 and 2 absorb moisture readily, both in the furnace and during pouring, giving off gases during solidification and thus causing the metal to rise in the ingot. Pouring temperatures are quite important; the 25 to 30% Cr alloy is the hardest to handle, for the columnar crystals may become very large, and these and the complex group 4 alloys should be cast into smaller ingots for forging.

of the starting temperature is essential. Pyrometric control is a necessity.

In heating it is preferable to charge ingots "red" hot to gas-fired regenerative soaking pits with the fire off, both for a practical reason, because it eliminates the danger of rupturing, and for an economical reason, because of the time saved. The thermal conductivity is low. Therefore extra heating time is necessary, yet too long heating enlarges the surface grains and



Pickled Cross-Section of 8x14-In. Billet of High Alloy Steel, Forged From a 13x16-In. Ingot. Analysis: 0.15% C. 24.7% Cr, 19.8% Ni. Proper rolling produces a structure in slabs, similar to that shown opposite

Conventional hot tops can be used to feed the body of the ingot. A characteristic ingot structure of 18-8 is shown on the frontispiece. In the medium chromium steels the columnar crystals extend only part way to the center, which is filled with equi-axed material. All types must be handled intelligently.

The low and medium chromium steels up to 20% Cr and the chrome-nickel group may be rolled direct from the ingot. The complex alloys and the 28% chromium steels must be forged into a billet. In all cases the rolling and forging ranges are narrow and a knowledge

makes the metal susceptible to surface cracking and checking. When reheating cold ingots normal procedure will suffice with the austenitic types, but extreme care must be taken with the straight chromium types, due to their low ductility. After brief soaking in the hot pits, the fire is turned on and the ingots heated slowly. Steels of group 3 require approximately 10 hr. for a 20-in. round ingot from the time of charging "red" till ready to roll (2300° F.). Groups 1 and 2 require approximately 15 hr. for the same size to go to 2225° F. All stainless steels are slow scaling, hence the long heating

periods do not introduce difficulty in this respect from a long time at heat.

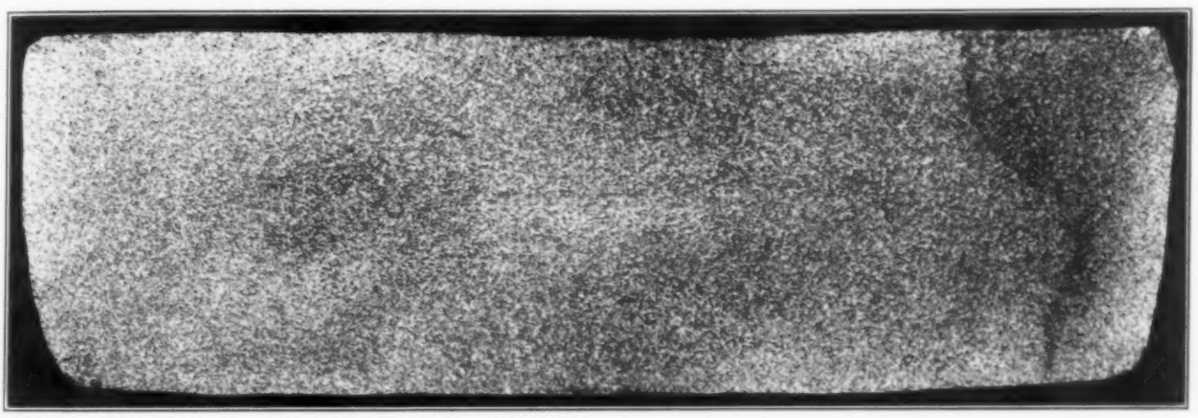
Blooming and Forging

On the blooming mill light initial drafts will avoid rupturing the corners or tearing the skin. Such defects do not heal with further working. Much depends upon the skill of the operator; he must watch the product carefully, especially the plain chromium steels. It is at times necessary to stop rolling and reheat the partially broken down ingot.

Ingots of complex alloys of group 4 and the 25 to 30% chromium steels must be reduced by forging. The heating periods are slightly longer and the forging temperatures approximately 50° F. lower than respective rolling temperatures. Ingots 13x16 in. can be reduced on first heating to 12½x15½ in. under a hydraulic press. The reduction may be the same after the second heating or it may be raised to 1 in. on a side. All depends on how the respective analyses behave in the judgment of the operator. After the ingots have been reduced 25% of their original cross-section, heavier reductions may be made with no fear of rupturing surface or corners. Finishing temperature varies with analyses from 1600° to 1900° F., it is high owing to the high strength of the stainless steels below this range.

Once the ingot has been broken down to slab or billet size all analyses may be rolled, but first the surface must be pickled and chipped (or ground) to remove all defects. The heating temperatures for rolling are generally lower; for example, low and medium chromium steels are rolled at 2050° F. or under while the chrome-nickel and complex group are rolled at 2250° F. plus. After each rolling it is necessary to recondition the surface by pickling and chipping (or grinding), since these steels scale but little, and any slivers, scabs, or scratches produced in one rolling would carry through and produce greater defects.

Slow speed hand mills in good condition, such as used for tool steel bars, are better than continuous trains. It is impossible to roll stainless steels with the same set-up used for carbon or alloy steels, since stainless tends to spread in the rolls, requires tighter guides, and tends to build up scale on the guides which soon mark the bar.



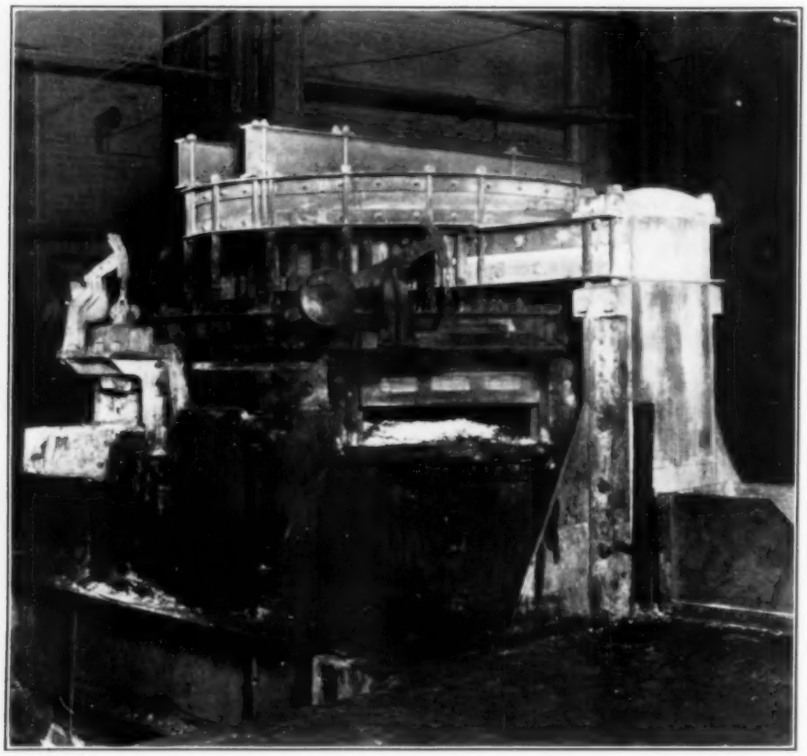
Cross-Section of 3-In. Slab of 18% Cr Steel, for Rolling in Sheet Mill, Shows That Ingot Structure Has Been Eliminated

Bars must be rough turned before being heated for piercing, for example, a 5¼-in. round to 5 in. Removing 0.015 in. is general practice in centerless grinding when the trade demands.

Sheet Rolling

If a substantial tonnage of one size of sheet bar is required, the bar mill or universal strip mill will be selected for rolling it. For smaller lots it is better to roll plate or slabs on the "jobbing" mill and cut it up into sheet bar sizes.

Previous to rolling it is essential that the surface be chipped and ground to remove all defects, pits, cracks, or slivers. Heating fur-



Single-Phase Ring-Type Induction Furnace Has Produced High Chromium Steels at the Rate of One Ton Per Hour in Long Campaigns

naces must be clean and free from dust and dirt. They are usually gas fired and slightly reducing to keep scale to a minimum. Due to the low heat conductivity of the stainless steels, the heating time is usually from 1½ to 2 times that for common steel. Usual starting temperatures for rolling of slabs are:

Low and medium chromium steels, 1800° F.
Chrome-nickel steels, 1800 to 1900° F.
Complex alloys of group 4, 2000° F.

Water under pressure is used to keep surfaces clean in the roughing passes. Plates are flattened while hot and generally sheared into sheet bar sizes while still warm (especially the low and medium chromium steels, which are decidedly more brittle at room temperature than at 300° F.).

Cleaning Sheet Bar

Sheet bar thus produced is pickled in 10% H_2SO_4 at 150° F. and ground free from any defects. Sometimes it is necessary to add a little HCl to loosen the mill scale. Sand-blasting is also employed at times to clean the surface, followed with a light pickle to bring out defects which must be ground out.

Heating or rolling equipment is essentially the same as for common steels.

Production from the standard rolls is about one-third that which could be obtained when rolling common steel sheets. One reason for this is that only a limited number of passes can be made before the stainless steels must be reheated. Furthermore, the reduction per pass is generally from 14 to 16% for stainless as compared with 25% for soft steel. Its rolling must still be considered an art. Starting and finishing temperatures are listed below.

		Starting Temperature	Finishing Temperature
Group 1		1500° F.	1200° F.
Group 2	16% Cr	1500° F.	1200° F.
	30% Cr	1800° F.	1500° F.
Group 3		1850° F.	1650° F.
Group 4		2000° F.	1800° F.

Thus the straight chromium types (groups 1 and 2) employ relatively low temperatures to obtain a fine grained finished product which will anneal to maximum ductility. They do not harden by cold work as readily as the austenitic and higher alloyed products, hence, they can be finished to a much lower temperature without cracking or other defects.

The low and medium chromium steels, if the carbon is under 0.12%, may be air cooled from their annealing temperature, which is 1400 to 1550° F. Hence they may be annealed in a continuous furnace. It is necessary to furnace cool or box anneal steels with carbon 0.12% and over to prevent martensitic areas.

Austenitic 18-8 steel is usually annealed at 1900° F. It is air cooled up to 16 gage and water quenched in this gage and heavier, whereupon all carbides should be in solution and the metal have a completely austenitic structure.

Treatment of the complex alloys depends upon their use and method of fabrication. They may or may not be annealed. If annealed the temperatures are high, usually 1900° F.

Annealing produces a scale on all analyses which is more difficult to remove. The usual pickle is 10 to 15% H_2SO_4 plus 5 to 25% HCl (both by volume) at 165° F. If this does not remove all the scale the sheets are scrubbed and again pickled in a milder solution of HCl plus HNO_3, or 10% HNO_3 plus 1½% HF at 130° F. Regardless of what solution is used, it is essential to finish with a dip in dilute nitric acid (10% by volume at 130° F.) to produce a passivated surface.

To produce a better surface for polished and decorative work it is necessary to reduce the sheet one or more gages in a cold mill. The ordinary sheet mill cold mills will not accomplish this, and it is necessary to use a cluster four-high mill or its equivalent. The type used in our mill has two very hard steel rolls 14 in. diameter and each of these is backed up with two 27-in. rolls. It is general practice to reduce 10% in gage, re-anneal, pickle, cold roll on ordinary cold mills, and roller level. For still flatter sheet it is necessary to stretcher level. This is followed by a rigid inspection for surface, gage, physical properties, cup ductility, special tests. The above cold reduction may be repeated after annealing as desired.

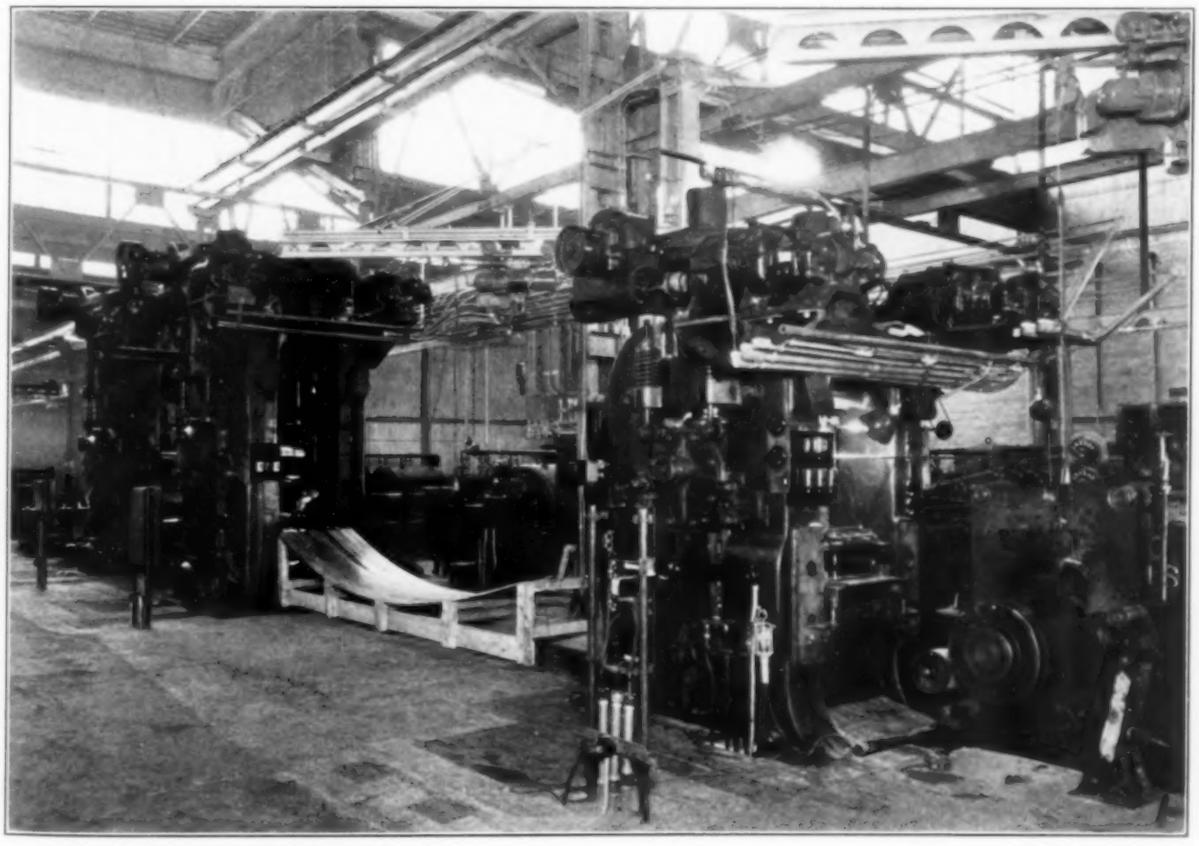
Strip Rolling

Slabs, with proper surface preparation, are sent to a hot strip mill for rolling into coils. In our operations, the slabs are usually 3 in. thick, 8 in. to 15 in. wide, and length to make 100 ft. of finished strip.

Slabs are heated in continuous pusher furnaces, and covered to prevent oxidation. Medium chromium steels should be heated no higher than 2000° F., to keep grain growth to a minimum. Others can be heated to 2150° F.

Slabs are broken down in a 24-in. reversible 2-high universal mill with vertical rolls. Correct reductions per pass are quite important to obtain the best surface and edge conditions.

Three Four-High Mills Placed Tandem for Cold Rolling Stainless Strip, Looking at Exit Side

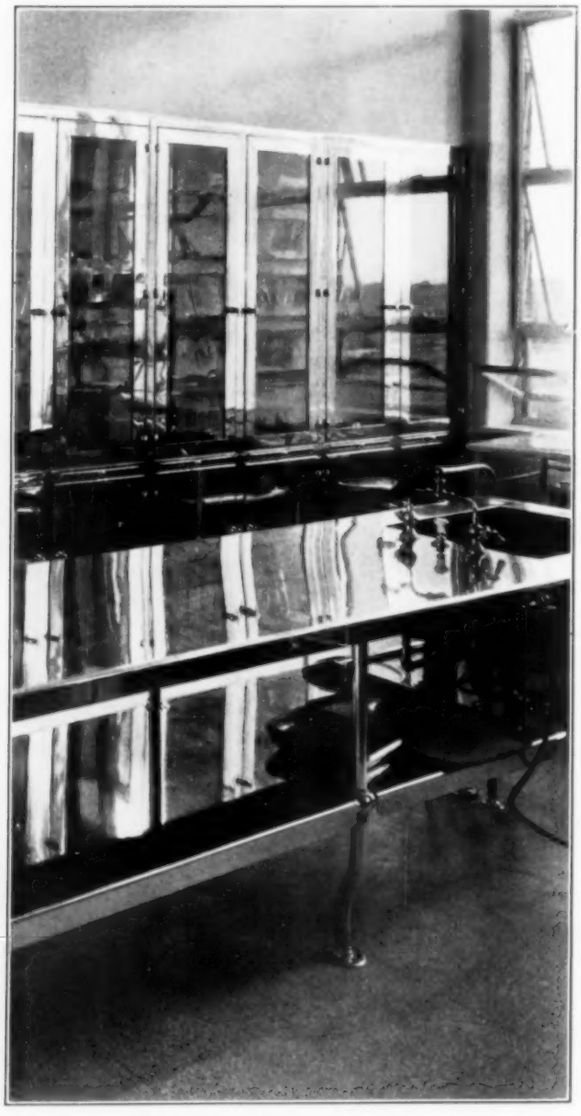


It is also advisable to have sufficient steam or water pressure to clean off scale.

Reductions for 3-in. slabs shown in the table at the head of page 27 are varied because of size and other conditions. Wide widths of chrome-nickel must be finished heavier, as this analysis cold works easily and requires considerable power for rolling.

Some alloys of the complex group 4 can be rolled into strip, but others (such as 25% Cr, 15% Ni, 2% W, or 25% Cr, 20% Ni) are too stiff and the edges crack badly due to narrow working ranges.

These alloys scale very little, and every precaution must be used to prevent scratching, as the bare metal is very susceptible to penetrating scratches and to galling on guides.



Instrument Cabinet at Providence Hospital, Detroit, Fabricated by F. O. Schoedinger, Columbus, Ohio, of Enduro Sheet With a Mirror Finish

Cold Rolling

Hot rolled coils are first annealed and pickled. The low chromium steels can be box annealed in coils or annealed in a continuous furnace. Temperatures of 1420 to 1480° F. will be satisfactory for steels with 0.12% max. C and 12 to 14% Cr and will produce hardness in the neighborhood of B-90 to 95 after continuous annealing. Annealing again at the same temperatures will soften further. Finally after several annealings and cold rolling, an anealed hardness of B-80 to 82 will be obtained.

When the chromium is kept between 11.5 and 12.5% with carbon 0.12 or 0.13%, the annealed hardness is slightly higher, but usually this range is desired for purposes which require full hardness, such as cutlery and other tools. By giving the strip a continuous normalize and then pickle, a high Rockwell of C-40 to 45 will be obtained. A slight cold roll pass will raise the hardness and improve the finish.

The medium group with 16 to 18% Cr is very popular in the automotive trade and has the largest demand in strip form. Annealing temperatures in the continuous operation are approximately 1550° F. A 30-ft. furnace is used, natural gas fired directly into the heating chamber with temperature control at each end. Annealed coils are pickled in either 15% HCl at 140° F., or 8% HNO_3 plus 1% HF at 120 to 130° F. Pickled strip is quite often passed through a series of rolls covered with emery paper to remove any remaining scale and small slivers or minor imperfections.

Chrome-nickel steels and complex steels are anealed at a temperature in excess of 1850° F. and pickled in the same manner.

The annealed and pickled coils receive the first cold passes through a tandem mill of three four-high mills (page 25). Two of them have 32-in. back-up rolls and 15x20-in. work rolls. The third has 24-in. back-up rolls and 9-in. work rolls. Elaborate electrical equipment easily adjusts the mills either singly or together, and controls the tension between mills. Special coiling arrangement on spools handles the coils

Steel	Reduction in Passes on 24-In. Mill									Three Passes 16-In. Mill			Final Thickness
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	
12 to 14% Cr	0.50	0.60	0.40	0.40	0.30	0.25	0.20	0.13	0.08	Varied to meet required gauge			0.125 in.
16 to 18% Cr	0.50	0.50	0.40	0.40	0.25	0.25	0.18	0.12	0.10				0.095 to 0.195 in.
18 Cr, 8% Ni	0.50	0.60	0.40	0.40	0.30	0.25	0.20	0.13	0.08				0.125 in.

for a second pass through the mill, or to the annealing furnaces.

Two passes through the tandem arrangement make a total reduction exceeding 30%. Typical passes for 16 to 18% Cr steel, starting with 0.195x8-in. strip, are 0.165, 0.135, 0.130, and 0.110, 0.100, and 0.095 in.

Coils are then annealed continuously through a 20-ft. furnace, gas fired, with a carborundum muffle. Atmosphere is sometimes controlled to permit proper pickling, which is done continuously before the strip is coiled ready for additional work.

Such cold rolling will be repeated through the tandem mill to a gage which will permit final passes through a two-high mill having highly polished rolls to bring up the best possible surface texture. Final anneals will be through the short muffled furnace, using temperatures of 1450° F. for the 12 to 14% Cr, 1500 to 1550° for the 16 to 18% Cr, and in excess of 1850° F. for 18-8.

The trade demands strip which will polish by buffing when the gage is below 0.030 in., while heavier gages will require grinding prior to buffing. For this reason the utmost care is needed throughout all operations to prevent surface defects.

The chrome-nickel grade has a varied demand, including soft and hard tempers. Since high physicals can be produced by cold working, it is possible to meet a demand requiring 200,000 lb. per sq.in. tensile, with corrosion resisting properties and other desirable characteristics. While these tensile values are high, the true elastic limit is very low, so that the engineering applications of hard temper varieties must be carefully analyzed.

The 25 to 30% Cr range has been cold rolled into strip, but the presence of free carbides makes it difficult to cold roll gages under 0.035 in. The working rolls become badly marked and worn after several passes.

An important operation in the production of stainless materials is polishing to different finishes of varied luster to meet trade requirements in different industries. This is a subject in itself, and has been discussed by C. C. Snyder in METAL PROGRESS, February, 1931.

In conclusion it may be said that acceptance standards have been constantly raised, thus continuing to present new handling problems to the manufacturer which means a continual change in methods of manufacture. Therefore, these products will receive a great deal of attention by the producer. This means the development of special equipment, and of especially skilled crews devoted solely to the production of these alloys, since there is a good potential market, and the necessity of making the product cheaper and better is constantly in the foreground.

Photo by Browning, New York

By M. E. Dorner
President, Cleveland
Cutter & Reamer Co.

Heat Treating in the specialty tool plant

RECENT developments in heat treating equipment have been the subject of numerous articles published in the technical press. Many have treated the subject from a scientific standpoint, giving the results of heat treatment under various combinations of time, temperature, and furnace atmosphere. Other papers have dealt with methods of heat treating metals on large scale production. For example: a most interesting article by David A. Nemser appeared in last February's METAL PROGRESS. It described the heat treatment of small tools in the large and modern plant of Pratt & Whitney.

Much of this published material, whether written from the viewpoint of the researcher, metallurgist, or production manager, seems to leave the impression that the highest grade of heat treatment is reserved for large scale production work and in the larger plants. This impression is not true. To prove this last statement this article will describe methods and equipment used by the Cleveland Cutter & Reamer Co., manufacturer of a wide variety of small tools used in the metal working industries.

A great diversity of tools are heat treated in this plant, ranging from $\frac{1}{8}$-in. end mills to 12-in. cutters; from small chasers weighing less than an ounce to reamers weighing as much as 50 lb. The materials may be high speed steel, oil hardening steel, or water hardening tool steel. The work is, therefore, very similar to that described by Mr. Nemser; the materials are essentially the same, and the qualities desired in the finished tools are the same. Accuracy, hardness and toughness are required by the purchaser of the tool; accuracy, to turn out a standard product; hardness, to give the proper cutting ability; and toughness, to enable the tool to stand up under shock. These three characteristics are functions of the steel used, the machine work done on it, and the nature of the heat treatment given with respect to the furnace temperature, furnace atmosphere and the length of time the tools are held at temperature.

The manufacturing problem at the Cleveland Cutter & Reamer Co. and similar tool shops differ radically from those of larger plants (which might be termed tool production plants). In the smaller shops there is an infinite variety of work which must be produced with a limited amount of equipment, and after a limited amount of experimental work. When a rush order calls for only two tools of a given specification and no further orders for such tools may be expected for a year or more, it is impossible to spend much time or money seeking for the ideal material and heat treatment for that particular tool. On the other hand, these tools must meet the highest standards of accuracy, cutting quality and durability.

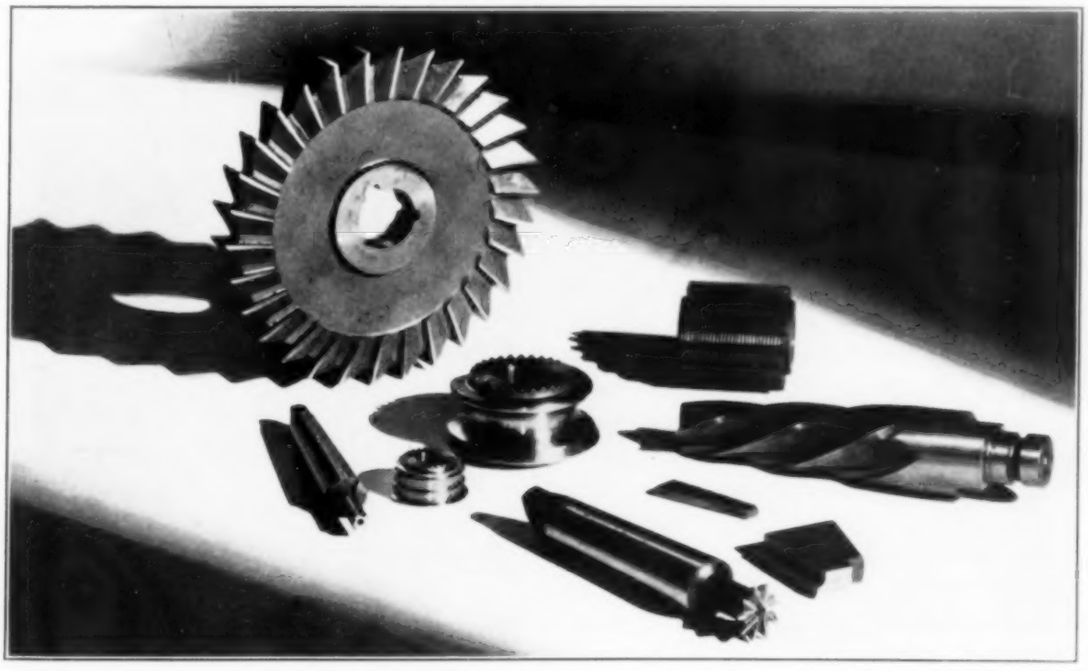
To meet these high standards, it is necessary to use the proper steel, fabricate the tool to the required accuracy, and give it a heat treatment that will produce the required characteristics of hardness and toughness, and at the same time retain that accuracy. This means.

among other things, that the heat treating equipment must be accurately controlled as to time, temperature and furnace atmosphere. In addition, it must be sufficiently flexible to enable one man, with one set of equipment, to heat treat a wide variety of tools during the day, and, by following simple instructions, to turn out, consistently, uniformly high quality tools.

There is no type of heat treating equipment that can eliminate the need of a skilled tool hardener. However, the experience of the Cleveland Cutter & Reamer Co. indicates that it is possible to install heat treating equipment which will make it easy for the heat treater to turn out high grade tools at all times. Through the use of such equipment the small production tool-maker can completely control his furnace conditions, and can take full advantage of the metallurgical advice of the steel manufacturer, and the findings of metallurgical research in general. He can also profit by his own experience, in that he is able to duplicate, at will, any heat treating operation which produced a tool of exceptional quality.

The search for heat treating equipment that would meet these conditions resulted in the choice of electric furnaces. The installation consists of three box-type furnaces and a vertical drawing furnace. A plan of heat treating department is shown on the next page. Two of the box-type furnaces, a large one and a small one, were designed and are used for hardening high speed steel. The large furnace has a door opening 8x12 in., a chamber depth of 18 in. and a variable power input with a maximum of 37 kw. The small furnace, used only when small tools are in production, has a working space 4x 8x12 in. and a variable power input with a maximum of 20 kw. Both are equipped with Globar electric heating elements. The third box-type furnace, which is used for preheating high speed steel and for hardening alloy and carbon steels up to 1850° F., is equipped with metallic electric heating elements and has a door opening 8x12 in., and a chamber depth of 27 in., and has a fixed power input of 15 kw. The vertical drawing furnace is of the Leeds & Northrup convection type, having a basket 14 in. diameter by 14 in. deep.

The temperature of these furnaces is automatically controlled and the instruments and control panels are conveniently located. The relative sizes of the furnaces are such that only one of the high temperature furnaces need be operated at a time, depending on the size of the pieces being hardened. A double throw switch transfers the power and thermocouple leads from one furnace to the other. One control in-



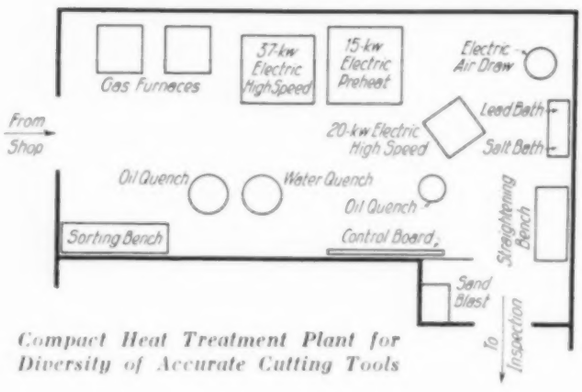
Samples From an Average Day's Production in a Small Plant Making Special Cutting Tools

strument and voltage regulating transformer is therefore sufficient for both furnaces. This is an economical arrangement and simplifies the shop wiring.

All three of the box-type furnaces were manufactured by C. I. Hayes, Inc. and are equipped with their "Certain Curtain" atmospheric control, which enables the operator to maintain a desired or specified furnace chamber atmosphere. The latter feature consists of a small combustion chamber under the throat, separated from the main work chamber, in which the proper gas mixtures are burned to produce the desired atmosphere in the furnace. The products of combustion leave the combustion chamber through a slot in the floor of the throat, to form a gas curtain across the door opening and to fill the furnace chamber. Natural gas from the city mains and air from a small blower are fed into the combustion chamber through pipes equipped with regulating valves and manometers to control and indicate the relative flow. When the furnace is at working temperature, the small combusion chamber is above the ignition point of the mixture of gas and air, and the nature of the products of combustion may be controlled by varying the relative flow of gas and air.

The need for controlled atmosphere has been known for many, many years. In the past, the heat treater has altered his furnace atmosphere in various ways — calling it "rich," "lean," "hazy," or "smoky." In fuel-fired furnaces this has been done by adjusting the burners or dampers. Since the same burners were used both for maintaining furnace temperature and for controlling furnace atmosphere, independent control of these important features was impossible. Each operation, therefore, resulted in a compromise between ideal atmospheric conditions and ideal temperature conditions in the furnace.

It is a matter of experience that different types of steel require different temperatures and atmospheric conditions. With the new furnaces at the Cleveland Cutter & Reamer plant, the source of heat — Globar electric heating elements in the high temperature furnaces and nickel-chromium resistors in the others — is independent of the atmospheric control. Thus the furnace atmosphere may be adjusted without in any way affecting the temperature in the furnace chamber.



Compact Heat Treatment Plant for Diversity of Accurate Cutting Tools

The correct furnace chamber atmosphere is obtained as follows: Each furnace is brought up to working temperature and a series of gas analyses made for various settings of the gas and air valves. The plotted data for one of these furnaces are given in the figure on page 31. The air was set at a manometer reading of 3 in. and the gas pressure was varied.

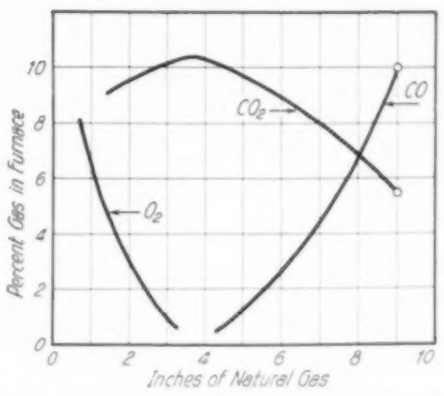
With the gas manometer reading 9 in. there is approximately 10% of CO and 5½% of CO_2, with no oxygen. This would be excellent for treating high speed steel at 2350° F., as it has been found that an atmosphere relatively high in CO prevents scaling, decarburization, and burning of the delicate cutting edges of the tool. Experience has also shown that tools heated in

Rough Surface From "Reducing" Atmosphere

such an atmosphere have, in many cases, qualities which do not seem to depend simply on the clean surface obtained. For instance, microscopic investigations indicate that grain growth in high speed steel is retarded when the steel is heated in an atmosphere high in CO and CO_2.

Similarly, it has been found that carbon steels, and the oil hardening alloys in the temperature range between 1450° F. and 1650° F., should be heated in an atmosphere entirely free from CO. This is assured by setting the valves to yield a small amount of oxygen. On a curve for this temperature range, similar to the one shown, the setting would be at a manometer reading of 3 in. for both gas and air. In practice, it has been found that one curve for each furnace, made within the average working temperature range, is sufficiently accurate for the hardener's use.

Experience, with the equipment described, has demonstrated that tools may be left in the furnace longer at soaking heat without danger of the "burning" so feared by the heat treater when using fuel-fired equipment.



Atmospheric Conditions in High Speed Furnace, Heated Electrically to 2350° F., When the Auxiliary Air Is Maintained at 3 In. Pressure and the Auxiliary Supply of Natural Gas Is Varied

A very important advantage of this feature, especially in small plants where the skilled worker is called upon to handle a great diversity of work and a large measure of the departmental supervision, is that the heat treater is entirely relieved of the strain of watching each tool in the white hot furnace. Absence of the fatigue incident to such strain materially raises his efficiency and is reflected in a greater uniformity of product.

Let us take a typical day's work and follow it through the hardening room to study the use of this equipment. It will include several types of steel and a wide variety of shapes and sizes:

High Speed Steel

6x½-in. Side Milling Cutters
3x⅛-in. Plain Milling Cutters
1-in. diameter No. 9 Shank End Mills
¼-in. diameter No. 5 Shank Spiral End Mills
⅛-in. Straight Shank End Mills
3x3-in. Spline Shaft Hobs
4x4-in. Spur Gear Hobs
3x2-in. Thread Milling Cutters
1¼x18-in. Line Reamers
1¼-in. diameter T-Slot Cutters
10x18-in. Metal Slitting Saws
3-in. diameter by 15-in. Taper Reamer
⅝x¼x2-in. Reamer Blades
⅜x1¼x2½-in. Inserted Cutter Blades
4x2x6-in. Dovetail Forming Tool

Semi High Speed Steel

2x1¼-in. Roll Turning Plugs

Carbon Steel

2-in. diameter by 10-in. Arbors
4-in. diameter by 5-in. Pilot Bushings

Oil Hardening Alloy Steels

Cutter Arbors 4-in. diameter by 8-in. long
Holders 3-in. diameter by 10-in. long
Cutter bodies 12-in. diameter by 2-in. thick
Reamer Bodies 4-in. diameter by 3½-in. long

After delivery to the hardening room, the work is grouped according to size and variety of steel. Since there are several large high speed steel pieces in this day's work, it is necessary to use the larger furnace. Earlier in the day, this and the preheat furnace have been brought up to 2350° F. and 1600° F. respectively. Each group, by size, is then put into the preheat fur-

Smooth Surface From Controlled Atmosphere

nace, so arranged that the bulkier pieces, requiring more time, are in the back part of the heating chamber.

After they are preheated, the tools are transferred to the high temperature furnace, brought up to temperature, and quenched. The correct atmosphere for the type of steel being heat treated is automatically maintained in both furnaces.

When the last of the high speed steel has been removed from the preheat furnace, the control instrument on this furnace is reset to the temperature specified by the steel manufacturer for the next type of steel to be hardened. If this type of steel calls for a change in the furnace atmosphere, the atmospheric control valves are adjusted to give the proper manometer setting. The work is then hardened and quenched in the proper medium.

Night Operation Economical

All tools after being quenched are placed in the electric draw furnace and brought up to drawing temperature. This furnace, as well as the other furnaces, is controlled by Leeds & Northrup instruments. By using the draw furnace at night, under entirely automatic control, it is possible to balance the electric load and keep the demand charge down to a minimum; a matter of importance to the owner of a small plant. This is one of the many ways in which economies can be effected.

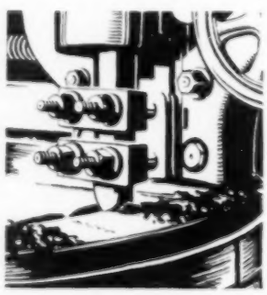
After drawing, the carbonized oil is removed from the tools by mud-blasting, sand-blasting, or pickling. They are then passed on for final inspection. This inspection consists of a Rockwell hardness test, a file test, complete check of the dimensions by micrometers and gages, and 40-diameter projection of thread-cutting tools to check the form and dimensions to tenths of thousandths of an inch.

Teeth of typical thread milling cutters are not ground, so it is necessary to control the dimensions and form of such tools within very close limits during the entire sequence of manufacturing and heat treating operations. It is only possible to do this consistently with the proper type of equipment, with respect to both forming and heat treating. Such cutters are given a most rigid inspection before leaving the manufacturer, and again by the customer before acceptance. Dimensional variations for each lot are carefully plotted and all must fall within the very close limits required.

Here we see the importance of proper heat treating equipment to the small plant. Most of the orders consist of only a few tools of a given kind, and any which do not meet the specifications constitute production losses. When there are only one or two pieces of each kind on an order, it is ruinous to lose even one piece in process. In quantity production, one may allow for a certain number of pieces being off standard. In small quantity special tool work this would mean the rejection of a large portion of an order, resulting in delay to the customer and a loss to the manufacturer.

Figures on pages 30 and 31 show two similar tools, one of which was hardened in the old fuel-fired furnace, the other in the Hayes "Globar" equipped furnace. They may be taken as typical examples of each system of hardening. "Blistering" and consequent loss of form of the tool, that is encountered when heat treating in fuel-fired equipment, has been entirely eliminated in the electric furnace with atmospheric control.

Two of the new box-type electric furnaces obsoleted four fuel-fired furnaces and while two of the latter are still in place, as shown in the plan, they have not been used since the installation of the new furnaces. This is largely due to the simplicity of operation, production efficiency, elimination of rejections, improved working conditions and accuracy of control inherent in the new equipment. It is for these reasons that even the smallest plants should be properly equipped in their heat treating as well as in their manufacturing departments.



By R. E. Waldron
Chief Engineer
Dominion Forge Co.
Walkerville, Ont.

and N. L. Deuble
Metallurgical Dept.
Republic Steel Corp.
Massillon, Ohio.

Heating Steel for Forging

furnaces & operations

Abstract of a paper for Buffalo Convention, A.S.S.T., October, 1932. Written Discussion Invited

SUCH a broad subject as "Heating Steel for Forging" may logically be divided into two portions — (*a*) some remarks by the first of the authors on modern furnace design and control and (*b*) some notes by the co-author on the speed at which steel will absorb heat.

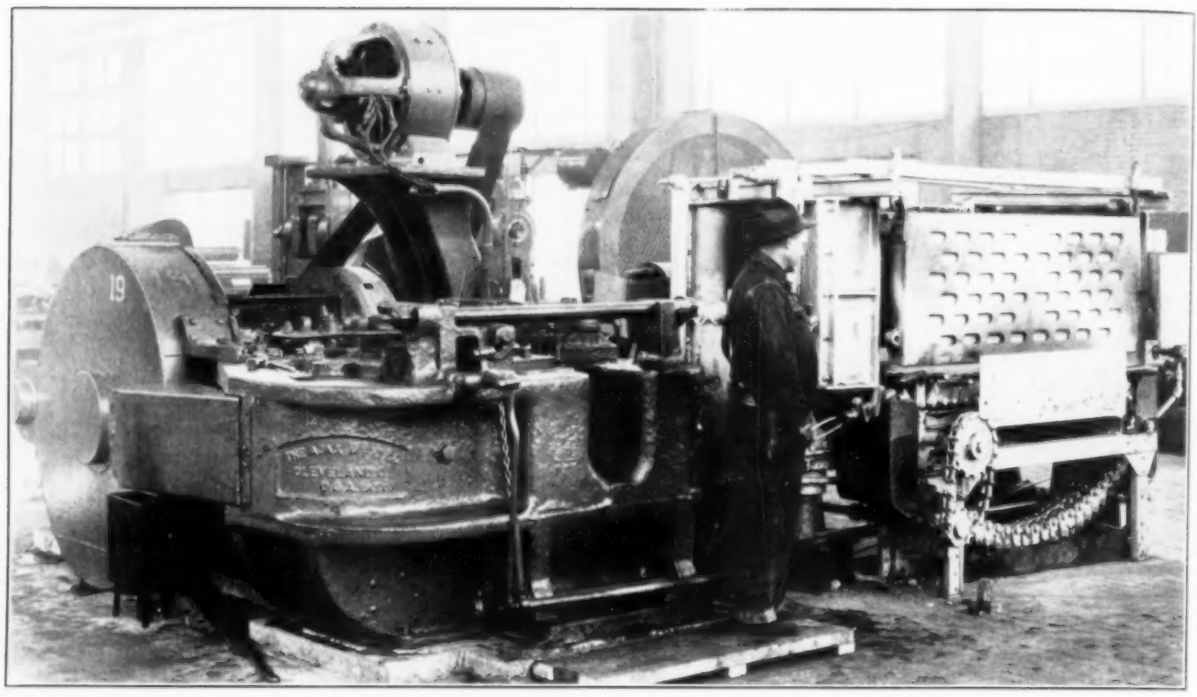
Earlier forge furnaces were very inefficient machines. Most of them are still unsightly, but the designer has greatly increased their efficiency; even in the batch type this may be somewhere between 15 and 20%. Such low efficiency is due to loss of heat in flue gases, which in furnaces at 2200 to 2400° F. is about half of the total heat liberated by the fuel.

In order to save some of this the continuous type of forging furnace has been developed. In them the products of combustion are carried out through some type of refractory tunnel through which the cold steel is entering and moving in the opposite direction. The steel is gradually heated, and the hot gases give up a greater portion of their heat. It is easy to take further heat from the gases by recuperators, and thus preheat the air used for combustion. The much lower temperature of the products of combustion and the reduction of heat losses by "black body radiation" through openings (in continuous furnaces as compared to batch furnaces) account for the increased efficiency.

However, the batch or in-and-out type of furnace is far commoner, particularly in shops which handle a large variety of steel sizes and shapes, and in such quantities as not to have special furnaces for certain parts. This classification includes those furnaces where the entire interior is the hot zone and also those in which the stock is passed mechanically from one side to the other. Most rotary furnaces also are batch furnaces rather than continuous furnaces, for their principal feature is mechanical handling of stock rather than preheating it by the hot exhaust gases.

There are, of course, innumerable variations. Rather than devote space to a list of them, it is better to describe the recent developments in design of box-type furnaces which fire from the rear. In this design the burners are placed in the wall opposite the slot opening and fire against the front wall. Suitable flues in the back wall balance the flow of hot gases and reduce the amount of hot gases escaping through the slot. This method of firing tends to more uniform heating and more satisfactory working conditions. Larger furnaces can be built; they are now working with slots up to 12 ft. long. The top arch is sprung from front to back, and as the chambers are usually not very deep, it eliminates the long arch span which would be required end to end. Depth from front to back must necessarily be greater than in an end-fired furnace, as it requires at least an 18-in. back wall to carry the flues and the flame must be long enough to avoid carbon deposits on the front wall.

Among the advantages are the following:



Slot Furnace Has Chain Conveyor to Carry Crank Shafts Through. One end heated for upsetting into flanged disk coupling. Courtesy Ford Motor Co.

More even heating conditions are obtained, due to the fact that the gases strike the front wall and are carried down over the work and back along the hearth. Burners and flues may be evenly spaced without flame interference (which produces hot spots within the furnace, a condition which prevails in the end-fired furnaces). Flues in the back wall also lend themselves very advantageously to recuperation.

As is always true, when one difficulty is overcome, we find others developing. The greatest is encountered in supporting the front wall and the top arch. Slot openings up to 80 in. are successfully spanned by so-called jack arch with one support in the center. Roof arches may also be supported on the end walls and built in the usual manner. This does not produce as good circulation of gases within the furnace but does eliminate a great deal of arch trouble. In other designs the front wall is supported by air or water-cooled castings; when this is done it is comparatively simple to spring the roof arch from front to back and carry half its weight on this front beam. However, if such supports are undesirable, the type of arch shown in the sketch may be used up to at least 12 ft., with two $1\frac{1}{2}$-in. supports.

Rotary furnaces have received considerable attention in the last two or three years, since they combine some of the features of the two main classes. However, it has proven to be very temperamental for forging work. Here again, we have several different designs, but all have two most important and inherent characteristics. First, the shape of the hearth is round and its area varies as the square of the radius, and unless the material to be heated is short and comparatively heavy for its length (or is of irregular shape which will lend itself to even spacing upon the hearth), the effective hearth area is greatly reduced. Second, no matter what method of heating is used, the maximum temperature must not exceed the melting point of the oxide scale which collects upon the hearth because no successful method has been devised to handle this slag. Even though refractories are used which are not affected by the molten scale, the moment the melted oxide reaches some point where it is cool enough to solidify, it clings to the hearth wall and slag spouts and will eventually ruin the hearth. Automatic temperature control is therefore necessary to keep the furnace in successful operation.

Automatic temperature control is itself a

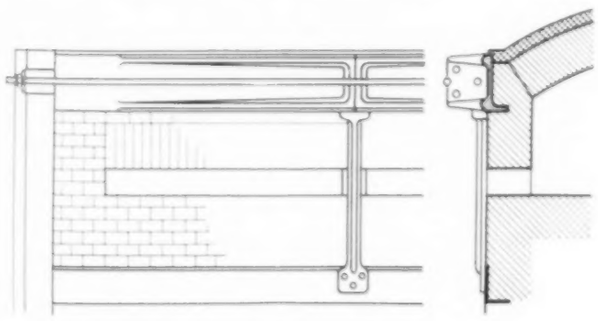
means of lowering the cost of forgings. A few of its outstanding advantages are: (1) It enables the operator to duplicate firing conditions; (2) it reduces fuel consumption; and (3) it lowers upkeep costs. There are also a great many intangible advantages.

In selecting equipment the most experienced advice should be sought. One standard cannot apply to all conditions. Since there is much vibration in the forge shop, very rigid instruments are required; yet they must be sensitive. Particular attention and study should be given to the relation between burners, valves, and controlling instrument. When these elements are properly chosen greater accuracy and uniformity are possible with automatic than with manual control.

All this automatic equipment is dependent for its accurate operation upon the thermocouple. Since most drop forgings are heated to 2000° F. and over, the noble metal or platinum thermocouple is most commonly in use. Platinum has a tendency to absorb gases and becomes brittle. It must also have adequate protection to insure long life and accurate measurement. It is a very good practice to check temperatures frequently with an optical pyrometer. The care of all control instruments should be placed under one department for supervision.

Automatic temperature control is by no means universal. There are disadvantages which to a certain extent offset the foregoing advantages.

In order to obtain full advantage of temperature control, as far as metallurgical conditions are concerned, the steel should be forged at the temperature of the furnace. To do this would require a long time for heating—much longer than is really good practice. Long heats produce a great amount of scale and increase the grain size of the steel; they necessarily slow up production or require furnaces of extreme size. Therefore, general practice is to control the furnace at some temperature *above* the required forging temperature of the steel, sometimes as much as 150°. This, of course, defeats the desired precision in billet temperatures, but it does protect the furnace linings, and inasmuch as the spread is a definite known amount, the steel does not rapidly reach a detrimental temperature during a slight delay. It also has a very marked effect upon fuel consumption (low furnace temperatures take better advantage of the available heat in the fuel).



Trussed Iron Beam Used to Support Front Wall and Arch Over Long-Slot Forging Furnace

Fuels

Electric furnaces have never been particularly popular in the forging industry because they operate at somewhat lower temperatures than fuel-fired. They are also expensive to operate and the cost per pound of steel heated is usually very much higher.

Among the fuels used, oil, of course, is the most widely used; second to that is gas, either natural or artificial. "Butane" is a third fuel which is being used to some extent; it is being marketed by several of the oil refining companies and is shipped and stored as a liquid. At the point of use it is passed through vaporizers and burned as gas, which is its normal state at atmospheric pressure.

City gas or other low B.t.u. gas is not economical except under certain favorable local conditions as to price. Gas-fired furnaces have always appealed to the average owner. With gas it is much easier to control the temperature; it is much cleaner; there is no storage capacity necessary with its attendant tanks, pumps, and heaters; and there is no carrying charge for fuel inventory.

Regardless of price, gas has not in the past been a very satisfactory fuel for forge furnaces because of the lack of luminosity in the usual flame. Recent developments of "diffusion combustion" not only produce a luminous flame but lay a blanket of raw gas over a uniform furnace charge in such a way as to produce heated steel with practically no scale. This matter was dis-

cussed at length by Mr. Hepburn in last month's METAL PROGRESS.

Furnace Calculations

There are several questions which must be answered at the outset: First, the number of pounds of steel to be heated per hour; second, the temperature to which it is to be heated; and third, the size and shape of the billets. With these questions answered, the first calculation is to find the hearth area.

The amount of steel heated can be varied considerably, particularly with manual temperature control. In an oil-fired furnace (in-and-out type) the figure is somewhere between 60 and 90 lb. per sq.ft. of hearth. If temperatures are exceedingly high, this can be sometimes increased to as much as 120 lb. but it is severe upon the refractories.

In calculating the effective hearth area it is necessary to know the number of pieces per hour, their projected area upon the hearth, and the length of time it will take to heat that piece under given furnace conditions. For the latter the curve on page 38 will be useful.

For maximum heating rate it is necessary to allow space between the pieces, usually equivalent to the width of small square stock, or one-half the diameter of round stock. Beyond 2 in. this clearance should be increased proportionately; with 4-in. square stock it should be twice the width.

Calculation of fuel consumption requires a knowledge of what becomes of the heat which is liberated in the furnace. By closely observing the operation of various furnaces and experimental tests, information and data have been gathered in the curves on page 37. The one at the top left shows the heat lost through a square foot of 4½-in. refractory wall backed up by 2½ in. of insulation. Radiation losses for other common walls are found by multiplying corresponding data from this curve by the appropriate constant K.

The top central curve shows the amount of heat radiated per square foot per hour from a black body at given temperatures. A uniformly hot furnace radiates much like a black body and therefore this figure applies to losses through all slot openings, burner openings and flues which have a projected area upon the radiant walls.

The third item to be figured, namely, the heat lost in any cooling medium (water or air) can be figured from its volume and the difference between entering and exit temperatures.

Useful heat, meaning that imparted to the material which we desire to heat, may be taken from the curve at the top right of the group on page 37, which shows the total heat required to raise one pound of iron (or steel) from room to the various temperatures.

In all types of furnaces, except electrical, heat is generated by combustion and the products must leave the furnace at the same rate at which they are generated. It may be assumed that such gases leave the furnace at average furnace temperatures. The heat lost in these gases is so large that it accounts for the very low thermal efficiencies of forging furnaces. The curves at the right on page 37 show the available heat of different types of fuel, that is, the total heat of combustion minus the heat carried away in the gases at furnace temperature.

A typical example is computed, which is self-explanatory. These calculations have been based upon an actual furnace. In operation it heated 1500 lb. of forging stock per hr. and consumed 21.1 gal. of oil per hr.

It is good practice to select burners of 25% more capacity than is required, especially for furnaces which are fired intermittently.

Heating Steel for Forging

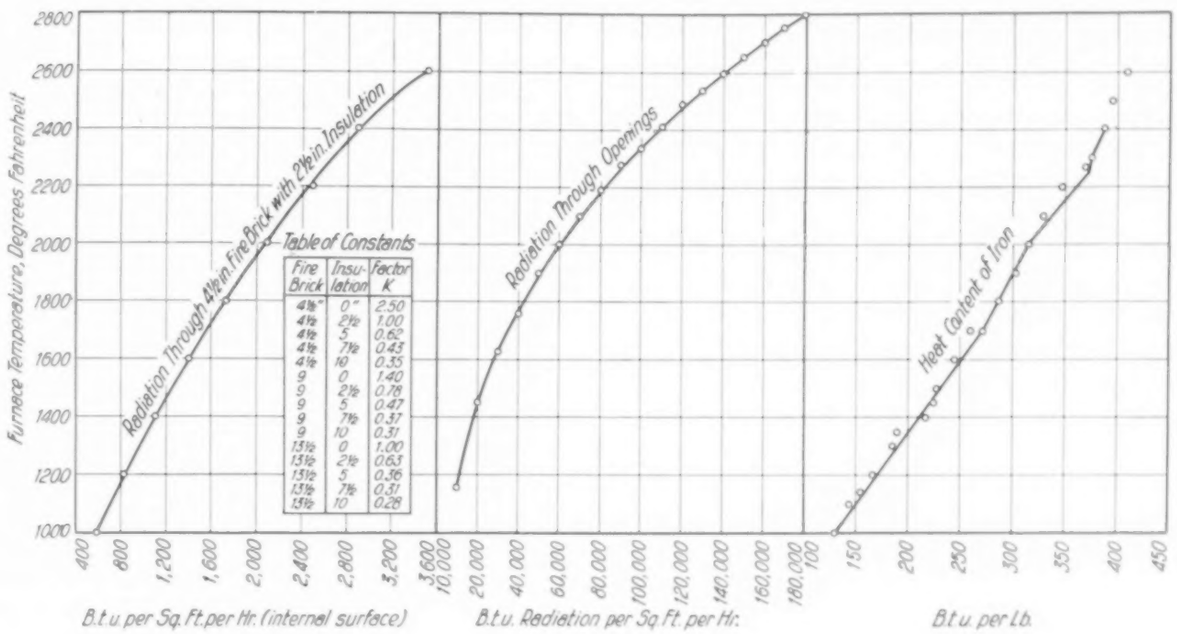
If steel did not expand on heating, if the grain did not grow, if the steel would not burn, then the forge man's problem would be simple. Just charge the steel into a hot furnace, heat as rapidly as possible to the dripping temperature, and forge!

Thermal expansion (and volume changes at the critical temperatures) sets up strains of tremendous magnitude. Cases have been known where a 35-in. ingot has been broken into several pieces as clean as if sawed. Furthermore, at too-high temperatures oxygen penetrates the grain boundaries and the steel loses its toughness and cannot be salvaged. Finally the grain grows more rapidly as the temperature is increased; time also is a factor here.

From the above, the forge shop's problem can be stated in the following manner: In order to make steel plastic, it must be heated. The higher the temperature, the more freely it will flow. If heated too rapidly, it will probably rupture in the furnace and if not there, then under the hammer, due to cold centers. Therefore, the problem is to select the most rapid heating time and the maximum working temperature for the metal and still be safe.

It is questionable if the majority of forge shops give the proper consideration to the analysis of the material being worked. This is important, as different rates of heating and maximum temperatures are necessary for different analyses.

Starting with the simplest analysis, that is, pure iron (as free from carbon, manganese,


Furnace Temperature, Degrees Fahrenheit
Radiation Through 4½ in. Fire Brick with 2½ in. Insulation
Table of Constants
Fire Brick | Insulation | Factor K
4½" | 0" | 2.50
4½ | 2½ | 1.00
4½ | 5 | 0.62
4½ | 7½ | 0.43
4½ | 10 | 0.35
9 | 0 | 1.40
9 | 2½ | 0.78
9 | 5 | 0.47
9 | 7½ | 0.37
9 | 10 | 0.31
13½ | 0 | 1.00
13½ | 2½ | 0.63
13½ | 5 | 0.36
13½ | 7½ | 0.31
13½ | 10 | 0.28
Radiation Through Openings
Heat Content of Iron
B.t.u. per Sq. Ft. per Hr. (internal surface)
B.t.u. Radiation per Sq. Ft. per Hr.
B.t.u. per Lb.

Fuel Required for Forging Furnace

Requirements: To heat 1500 lb. steel per hr. to 2300°F with fuel oil, no excess air
Furnace at 2400°F

Area of hearth: $\frac{1500 \text{ lb.}}{75 \text{ lb. per sq. ft.}} = 20$ sq. ft.

Economical depth of furnace = 42 in.

Length of hearth: $\frac{20 \times 12 \times 12}{42} = 68$ in.

Size of furnace indicated: 66 in. wide, 42 in. deep, 30 in. high
slot: 60 in. long, 6 in. wide

Area of 13½-in. ends and back =
$= 42 \times 30 \times 2 + 66 \times 30 = 4500$ sq. in. $= 31.2$ sq. ft.

Area of 9-in. front, hearth and arch =
$= 66 \times 30$ (includes slot) $+ 66 \times 42 + 66 \times 42 \times 1.1$ (arch factor) =
$= 7800$ sq. in. $= 54.1$ sq. ft.

Radiation through 13½ in. walls =
$= 31.2 \times 2900$ (from curve) $\times$ factor 1.0 $= 90{,}000$ B.t.u. per hr.

Radiation through 9 in. walls =
$= 54.1 \times 2900 \times 1.4 = 210{,}000$

Radiation through slot (2.5 sq. ft.) plus
0.5 sq. ft. other openings $= 3.0 \times 110{,}000 = 330{,}000$

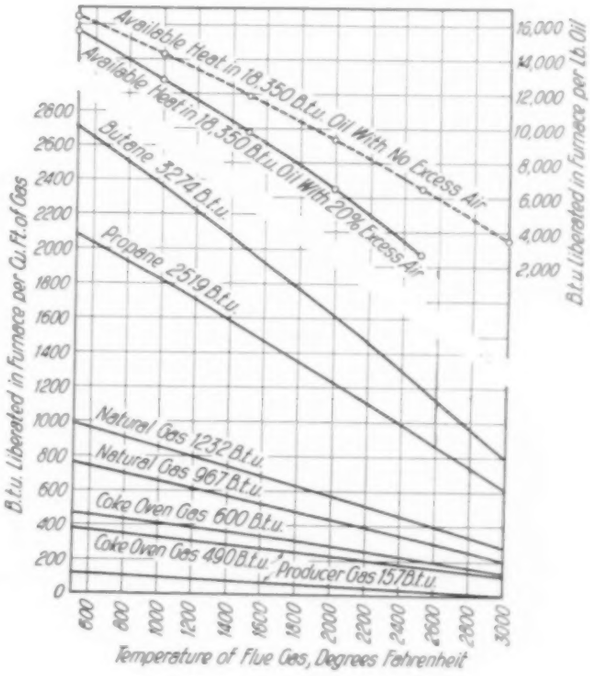
Absorbed by steel $= 1500 \text{ lb.} \times 375 = 560{,}000$

Total heat required $= 1{,}190{,}000$ B.t.u. per hr.

Heat available in oil (flue gas at 2400°) $= 7300$ B.t.u. per lb. (from curve)

Oil needed for furnace $= \frac{1{,}190{,}000}{7300} = 163$ lb. per hr.

$= \frac{163}{8} = 20$ gal. per hr.


Available Heat in 18,350 B.t.u. Oil With No Excess Air
Available Heat in 18,350 B.t.u. Oil With 20% Excess Air
Butane 3272 B.t.u.
Propane 2519 B.t.u.
Natural Gas 1232 B.t.u.
Natural Gas 967 B.t.u.
Coke Oven Gas 600 B.t.u.
Coke Oven Gas 490 B.t.u.
Producer Gas 157 B.t.u.
B.t.u. Liberated in Furnace per Cu. Ft. of Gas
B.t.u. Liberated in Furnace per Lb. Oil
Temperature of Flue Gas, Degrees Fahrenheit

silicon, and other elements as possible), it may be heated rapidly to about 2300° F.; however, upon forging, due to the red-short range, all working must be stopped at about 1800° F. and not worked again until below 1550° F.

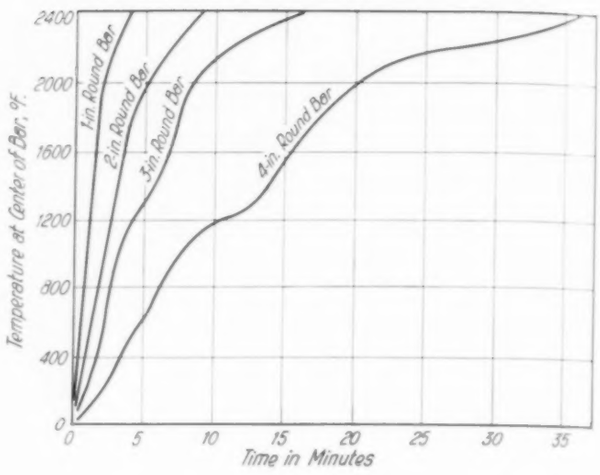
Increasing the carbon and manganese content eliminates this range. As a rule, no difficulties are encountered in heating plain carbon steels in moderate size up to 0.50% carbon. Harder steels, except in very small sizes, should be preheated up to 1400° F. and from there they can be heated rapidly. Of course, as the carbon is increased, the maximum temperature should be dropped to about 2000 to 2050° F.

Alloy steels must also be heated more carefully, especially when the alloy content increases. Low alloy steels containing less than 0.40% C do not present any difficulties in heating except that they require more time to heat thoroughly and do not flow as readily as the plain carbon steels of the same carbon content. They should not be heated above 2200° F.

Silico-manganese and straight manganese steels, especially the latter with 1.75% Mn, are subject to rapid grain growth. They should be heated to the lowest initial temperature to finish the forging and held no longer than to insure thorough heating. S.A.E. 9200 steels should be finished at 1650° F. or lower; heat treatment will then impart considerable toughness.

Steels such as the S.A.E. 3200, 3300, or 3400, containing over 0.25% carbon, S.A.E. 52100 and special steels higher in alloy content are called "sensitive steels." Low alloy steels over 0.40% C and straight carbon over 0.85% C should also be included. As the alloy and carbon content and size increase, the necessary precautions become more complicated; these steels should be preheated to 1400 to 1600° F. Some small sizes and low carbons can be charged into the forge furnace if the temperature is dropped slightly. The maximum temperature can be generally limited to 2150 to 2200° F. Careful cooling after forging is necessary, as will be noted below.

It is hard to say which is the most important consideration when heating steels for forging, analysis or size. In general, sizes up to 4 or 5 in. square of carbon steel up to 0.50% and the ordinary alloy steels up to 0.40% C can be safely charged into a forging furnace at heat, if it is small enough so there is some drop in temperature. From 5 in. square to 12 in. square these steels can be safely charged into a furnace at 1400 to 1600° F. and allowed to absorb some of the heat before firing. Larger sizes should be charged into a cold furnace and preheated to 1600° F. before transferring to furnace up to forging heat. Some operators will, at the end of the day, charge their large billets or blooms into the cooling furnace at about 1600° F. and allow the steel to absorb the heat from the furnace, and start firing about 3 A. M.



Time Required to Heat Round Bars to Center in Furnace at 2450° F.

While the heating of large sizes is of extreme importance, the cooling is of equal importance, for the steel then goes through the reverse cycle. The ordinary alloy steels up to 0.40% C and the plain carbon steels up to 0.50% C should be pit cooled or piled so that they cool slowly and uniformly if the sizes range from 5 to 12 in. square or equivalent cross-sectional area. Over 12 in. square they should be furnace cooled.

Practically all sizes of the sensitive steels should be furnace cooled in order to eliminate any checks which would result from non-uniform cooling. Very small sizes, which finish quite cold, are excepted.

One point which is often overlooked by the forge man, especially in the sizes from 8 to 20 in. square, is that some steels are denser than others. An open steel will stand more abuse in heating and working than a well-killed heat of the commercial grades. Electric furnace steel is generally denser than open-hearth steel of the same analysis.

By G. V. Luerssen
Carpenter Steel Co.
Reading, Pa.

mill inspection by Deep Etch

Abstract of a paper for Buffalo Convention, A.S.S.T., October, 1932. Written discussion invited

FROM the viewpoint of the steel maker the purpose of disk inspection is twofold. Its first and most important function is to prevent the shipment of inferior material to the customer. This function becomes of extreme importance where expensive tool steels and high grade alloy steels are on the order.

The second function is to afford the steel maker a close and constant check upon his own manufacturing practice both in melting and in hot working. Disk inspection would never be entirely effective simply as a weeding out process. It must be made to yield information regarding the product which can be used in elevating the general standard of quality. Such information can be obtained through the medium of carefully correlated records, preferably kept by order of heats.

Any method adopted should therefore be built around two principles, first, that of consistently supplying the customer with satisfactory material, and second, that of carrying out the method on the most economical basis possible. In general, the procedure which embodies these principles most effectively inspects the semi-finished material — in the case of tool steel, the billet.

One outstanding advantage in this practice is the ability to procure results of inspection a very short time after the melting of the heat. A prompt and methodical check-up on melting practice is thus obtained, and any necessary adjustments can then be made with precision. It also prevents the accumulation of questionable material.

A second advantage of billet inspection lies in the fact that steel can be inspected in full heats, and thus it provides a more comprehensive study of melting practice than is possible after the heats are broken up.

A third advantage, and one of extreme importance, is the saving in time by avoiding delays contingent upon rejecting finished material, an advantage which is quite real where definite delivery dates are to be met. A final bar inspection obviously does not insure against such delays. Inspection in the billet, on the other hand, minimizes this hazard since it eliminates any guess work as to the quality of the material going into the finished bar.

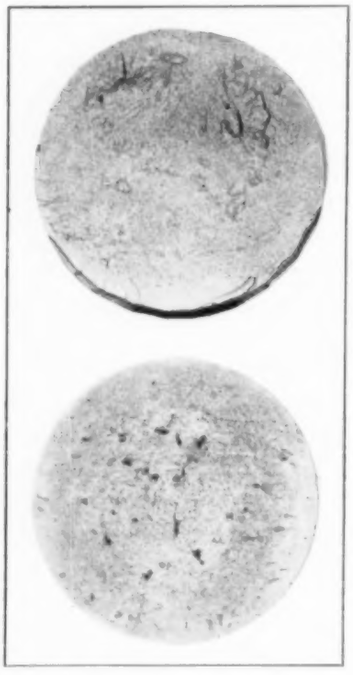
A fourth advantage is the saving of material due to the ability of the inspector to recognize certain defects characteristic of tops or bottoms of ingots. These can readily be eliminated by

cutting back. It might be mentioned here also that a more thorough inspection can be made on a billet than on a bar for the reason that defects are larger.

The method as outlined presupposes that no material defects can be introduced by the final rolling or forging of the bar. Experience has proved this to be a safe assumption, the only requirement being that reheating temperatures and hot work practice be controlled within reasonable limits.

If bars are of very large sizes, an inspection of the finished piece will be cheaper and will give a final check on heating and on the final forging conditions.

It might be added that disk inspection is distinctly a test for macrostructure, and not for microstructure. Consequently, whether conducted upon the billet or upon the final bar, while it detects material defects and segregation, it is no guarantee of the annealed or treated structure of the bar, and this can only be determined by the microscope.



A Bar That Looked Pretty Good on Fracture Wasn't so Hot After a Deep Etch

Preparation of the Billet — Through all operations it is desirable to handle the material in units of heats, and to cut as few billets as necessary. If the ingot is cut in two, the top and bottom billets are properly marked. If the ingot is cut in three or more, the middle billet should also be identified.

It is usually necessary to anneal the billets for cutting carbon steel over about 0.70% carbon and the harder alloy steels. A semi-anneal is sufficient — that is, heat the steel to the regular annealing or spheroidizing temperature, but cool much more rapidly.

Cutting — Disks are usually cut on band saws or high speed hack saws. Round billets may be cut with a parting tool on a lathe or cutting-off machine. Each disk with its corresponding billet-end is stamped with the heat number and a serial number. A 100% inspection of the heat is made; disks are taken from points representing top, middle and bottom of each ingot (except when one ingot makes a single billet, in which case only tops and bottoms are inspected).

Careful cutting gives a cleanly sawed disk, and no further preparation is required. Disks cut with the parting tool may be dragged, and should then be ground.

Etching — Etching is usually done in a 1:1 solution of hydrochloric acid in water. Duriron dishes have been found very convenient and durable. Disks are etched for a prescribed time at a definite temperature depending upon the type of steel, and then scrubbed in clear water and dried with absorbent paper.

Inspection — Intelligent inspection requires not only experience and good judgment to determine which is good and which bad, but knowledge of melting and hot working operations, and an understanding of the physical and chemical processes underlying the various patterns developed by the etch. The action of acid on the various constituents must also be understood, and its tendency to magnify some of these must be recognized.

Inspection standards must be established largely through experience and knowledge of general requirements in the trade. There is, of course, no question concerning obvious defects. There are some characteristics, however, which are the result of natural processes of freezing, and consequently are always present to some extent. Whether these can be considered defects or not depends upon their degree. Principal among these are the natural increase in pitting from surface to center and the development of dendrites. The type of steel being inspected must also be taken into account since not all steels respond alike to etching. Here the inspector's judgment is very important.

As already indicated, it is convenient to classify defects under two general groups, first,

those which are characteristic of extreme top and bottom of the ingot, and second, those which are characteristic of the entire heat. The former can be removed by cropping back until the etched disk shows the billet to be clear. The second type of defect governs acceptance or rejection of the entire heat upon the basis of some established standard. With proper control in melting and hot working based upon inspection data, it is possible to raise the general quality well above this standard.

As the inspection and cropping of each heat is completed, it is released for final rolling or forging, carrying with it a distinguishing mark to indicate that it has passed. Adequate records are of great importance, and in order to be most effective, are kept by heats, and submitted regularly to the operating departments interested.

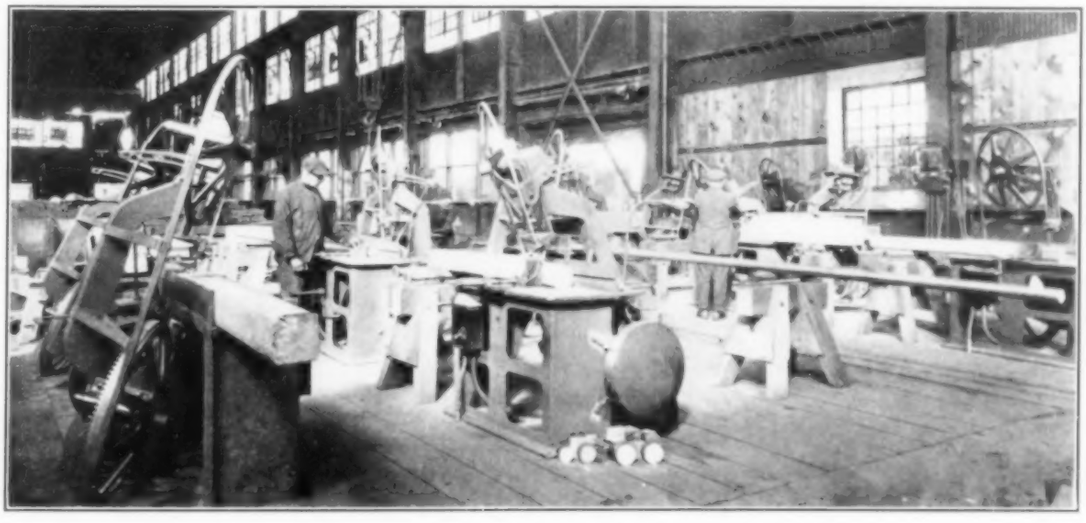
Many cases are encountered in which consumers require a special type of inspection to meet certain peculiar conditions in their service. It is then often necessary to depart somewhat from the routine method, and occasionally to make alterations in manufacturing practice. Many of the specifications encountered are quite interesting, showing how ingeniously the etch test can be employed to indicate the particular properties in which the consumer is interested. In general, however, it is an advantage to both consumer and maker to adhere as closely as possible to some generally accepted standards, such as those tentatively prepared by the American Society for Steel Treating.

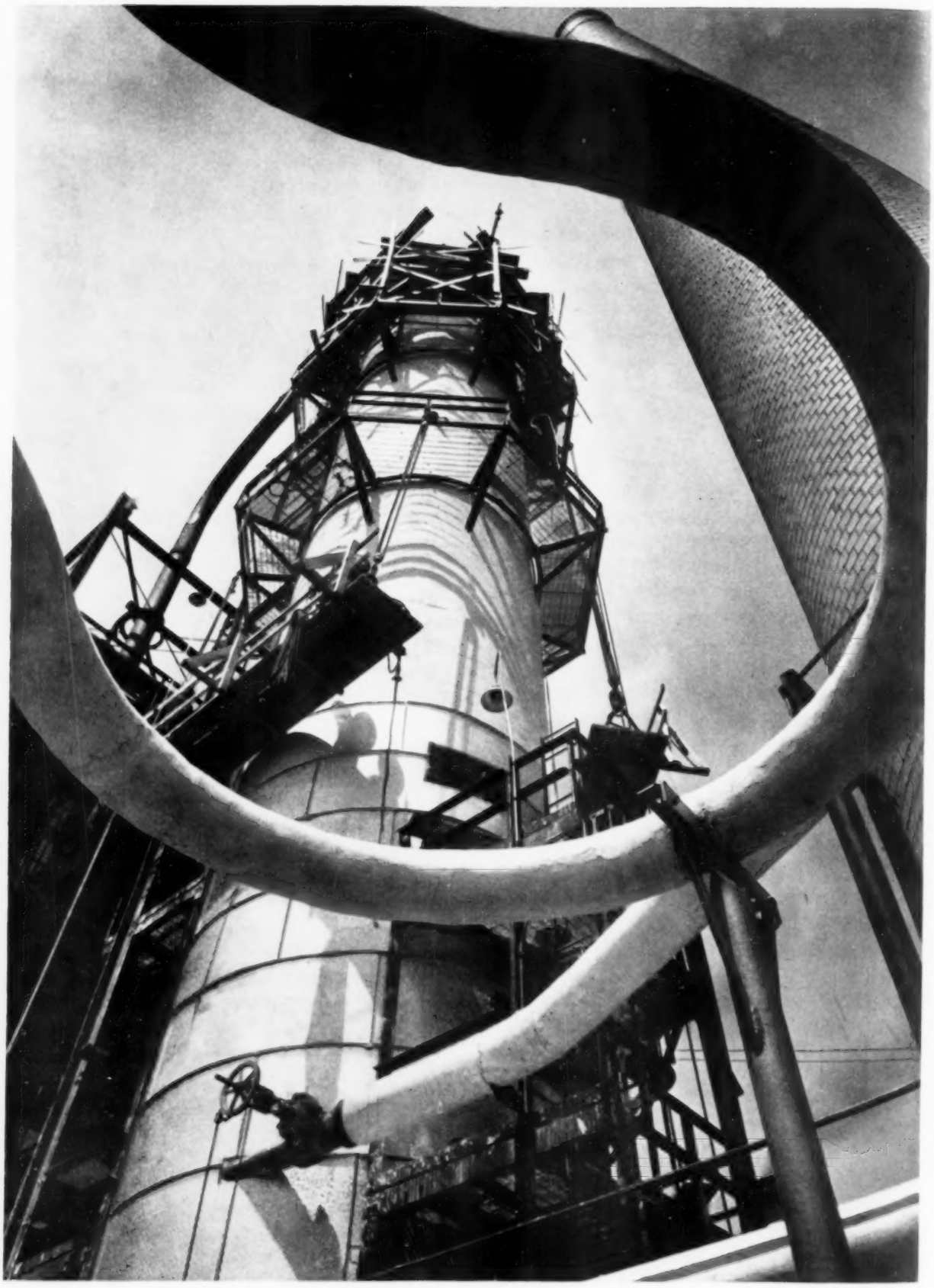
In conclusion it may be pointed out that the quality steel maker is striving for a perfection which he will probably never attain. Steel making is essentially a chemical process carried on at extremely high temperatures. Unfortunately, at such temperatures the furnace and ladle enter into the reactions. Furthermore, the process must be carried out in an atmosphere of nitrogen and oxygen, the latter of which combines readily with most of the elements in the steel. Lastly the product itself is of such a character that it tends to freeze, not in a homogeneous mass like glass, but selectively in a crystalline mass.

Thus with even the closest attention to details in melting and pouring, there are certain inherent conditions which cannot be entirely controlled, and which will consequently vary slightly heat to heat and between parts of the ingot. Such variations, of a very slight order, may be magnified by etching so that they become not only perceptible, but often quite striking. This magnifying power, while the very thing which makes the test valuable, must be taken carefully into account.

The success attained in using the test really is measured by the degree of cooperation between maker and consumer. It is necessary for the maker to understand thoroughly the requirements of the user, and for the consumer to recognize some of the general problems which are encountered in steel making. Fortunately, better mutual understanding is growing.

Series of Band Saws Used to Crop Billets for Etch Inspection





Welding Is Indispensable to Oil Refiners

Photo by Rittase

Heat and Metal Wasted

PREDICTIONS, from the high places of politics and business, of a nearby turn for the better have so often miscarried in the last three years that anyone would be foolhardy to venture another except on the ground that we have already sunk so low there is no other way to go but up. This would be one reasonable basis for the belief that the gamblers in securities are right in betting on better business in the near future.

Any concurrent awakening of faith in the hearts of bankers and industrialists should mean that happy times are here again for members of the American Society for Steel Treating. Competition will cause an insistent drive for production without waste, which should redound to the benefit of those intelligent enough to sell their experience and sound ideas.

In only one branch, take furnaces: An estimate was recently made that in the metal fabricating, machinery, and transportation industries (exclusive of iron and steel plants) there were approximately 25,000 factories or shops containing the enormous number of 120,000 furnaces for heat treating, forging, or enameling. It is safe to say that nothing better than more-or-less skilled labor and rule-of-thumb foremen are supervising these operations in at least 20,000 of the plants, and that 100,000 of the furnaces are wasteful in the extreme, not only of heat but of good metal mistreated thereby.

This certainly is a fertile field for development and improvement.

Desired Qualities of Weld Metal

IT IS too bad that the word ductile, which has always and from its derivation meant ability to be drawn into wire (just as malleable has meant ability to be hammered into sheets), has been given far wider meanings by recent usage. The resulting lack of precision was responsible for much confusion of thought in an interesting discussion on "the need of ductility in welds and welded structures" held by the American Welding Society last spring. One speaker meant elongation and contraction in a tension test when he said ductility; another meant ability to bend without cracking. They had better have used the word plasticity, as did a third when he defined crackless plasticity as that much-desired property of resisting any spread of cracks from localized high stress, which makes for high endurance to alternating loads. Another engineer implied that ductility meant toughness in impact. Lastly, the word was used for the general high quality possessed by metal free from segregation, blow-holes, slag inclusions, tiny cracks, and high internal stress.

Obviously, any metal should have that kind of "ductility," and no one would criticize the speaker for asking that commercial weld metal have it. Yet he was expressing a hope rather than an achievement, for what was under discussion was not "Should a joint have all the properties of the metal it connects?" — for that is a description of an ideal, a jointless joint — but this: "Should the metal in welded joints be harder and stronger than the mild steel it connects, or should it be softer and more plastic?"

Stated in this way, the answer is evident to any realist. He knows that all commercial methods of fusion welding produce metal that is harder, stronger, and less plastic under overstrain than rolled mild steel plate or pipe. He also knows that this is one important factor in the growth of the business; welded joints are unique in this property; mechanical joints are all weaker and less elastic than the metal joined. Welded joints have been accepted by careful engineers (for a long time in spite of higher costs) because of this very fact.

So, for the most part, the actual question as stated above is academic. Years ago the late S. W. Miller presented an analysis of typical joints indicating that the more plastic base metal could be expected and properly *should* be expected to readjust its internal configuration to

relieve dangerously high stresses due to unequal heating, small errors in fabrication or design, and the normal overloads in use. Abuse in service will ruin anything, but large abuses in fabrication and design can be avoided by proper material and workmanship, assembly, stress relief, and proof testing. All these things he classed together as "procedure control," and all later experience proves that Miller was correct.

In the present state of the art the only practical aspect in the question relates to joints in extra strong or alloy steel. It is also possible that with special rods and technique, by welding in controlled atmosphere, or with the aid of clever heat treatment, a joint could be made in a pressure vessel or seamless pipe that would have lower yield point and greater elongation than the metal on either side. Would anyone be justified in doing so? The answer clearly is "No." When such a thing can be done, it will also then be possible to make joints substantially equivalent to the base metal, which, of course, is the ideal condition.

Meanwhile, hundreds of thousands of butt joints have been made in seamless or special processed pipe (the metal of which has an ultimate strength of about 75,000 lb. per sq.in.) which have endured cold bending when the line was laid that stretched the metal 10 to 12%. These welded joints have given most excellent records in pipe line service where internal pressures are high — the factor of safety is as low as 1 or even 3 — and where erection and temperature stresses are severe. The metal is sound and strong, it makes a true weld with the abutting metal, yet it is relatively unyielding.

It is not intended to convey the idea that the history of the art contains no failures. But it is an undoubted fact that as the various elements of design and fabrication are mastered, the soundness and other good qualities of the metal in a fusion weld have been correspondingly enhanced, and with them have improved resistance to impact, ability to deform without cracking and those other qualities which are sometimes loosely grouped together in the word "ductility."

We may rest content with the statement, therefore, that as long as it is impossible to match exactly the properties in the base metal, weld metal should have a higher yield point and a lower elongation — as indeed it does.

New and Yet Newer Tools

IT HAS BEEN often remarked that progress in the technical arts is not continuous, but advances rapidly for a time when a new discovery is being studied and adopted, and then stagnates until another fundamentally novel fact is uncovered. Take the recent history of cutting tools:

Plain high carbon steel, quenched and tempered, is the old-time material. Mushet was the first pioneer in modern tools, developing the air-hardening tungsten steels during the 1860's for cutting very hard metal. In 1900 the Taylor-White high speed steel was exhibited at Paris; it also required a radically new analysis and heat treatment, and the next decade was spent in perfecting the alloy. Shortly before the War, Haynes discovered stellite, alloys of cobalt, chromium, and tungsten which were intrinsically hard as cast — but at the time it appeared to be a unique material. So the matter rested until 1927 when German investigators synthesized an excessively hard, wear-resistant tool material from powdered tungsten carbide and metallic cobalt binder. Possibilities of improving this by controlling the size and analysis of the ingredients have drawn numbers of experimenters to the problem and notable progress has been made in the short intervening time. As if this is not enough, rumors are now spreading of wonderful new metallic alloys about ready for exploitation for tools. These are said to be heat treated for high hardness, much as Sykes' iron-tungsten and iron-molybdenum alloys announced six years ago.

It is evident that in the matter of tools we are not only going ahead by leaps, but the leaps are getting closer and closer together. Can there be any limit to this progression?

By Ralf S. Cochran
Metallurgical Engineer
Surface Combustion Corp.
Toledo, Ohio

Design of heat resisting castings

Abstract of a paper for Buffalo Convention, A.S.S.T., October, 1932. Written discussion invited

A FEW years ago the measure of good furnace construction was bulk or mass. If a "mechanical" furnace was mentioned, one with a pusher was meant. Heat resisting alloys can be credited with introducing an entirely new basis of furnace design, and today, heat resisting alloys carry the metal through the hot zone. Since one of the most interesting applications of the new alloys is the walking beam conveyor for sheet steel, this specific type will form the basis of a discussion of the design of heat resisting alloy members and their performance in service.

Walking beam conveyors were first used in lehrs (glass annealing tunnels) as early as 1860. The rails were iron (the temperature being low) and were often faced with asbestos to avoid scratching the glass.

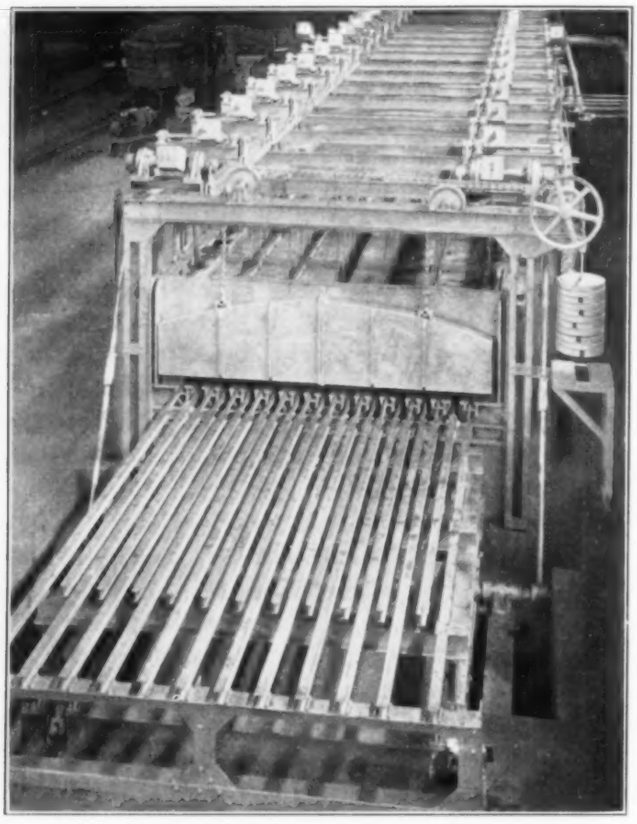
Some furnaces for higher temperature have been built during the last 30 years where the steel beams were faced with firebrick. Such a conveyor could not be underfired, so it never was adopted in the sheet mills. Air sucked up between the beams would also scale the steel.

Although suitable heat resisting alloys were known some years previously it was not until 1928 that anyone would use it for structural purposes or mechanical parts. The important functions required were (1) to support loads at high temperature without excessive creep or deflection, (2) to resist corrosion by hot sulphur-bearing flue gases without being brittle at the working temperatures, (3) to introduce no catalytic action on steel or gas that would interfere with the correct processing, and (4) to resist wear at non-lubricated surfaces. This seems a formidable list, but it has been surmounted. The practical success is measured by about 5000 beams now in service. As remarked at the outset, they have introduced an entirely new basis of furnace design.

When the first walking beam conveyors for sheet pack heating and normalizing were designed there was little known about the behavior of alloys under heat. It was anybody's guess what the coefficient of friction on sliding surfaces would be. As to strength, the alloy manufacturers advocated a design stress ranging all the way from 300 to 10,000 lb. per sq.in. at 1500° F.

It was opportune that a few creep stresses at high temperatures were available. These were assembled, a liberal factor of safety was thrown in, and designs were produced on this basis. Fortunately, experience has proved that this was on the conservative side; very few failures have resulted except those due to abuse by badly overloading, overheating, or both.

Since then a large amount of experience has accumulated by which these earlier designs may be refined. In view of the high cost of the alloys, unnecessary metal must be eliminated, yet one must be sure that the part will continue to function for a reasonable length of time, say three years. The result has been progressive lighten-



Discharge Table of Sheet Normalizer. Moving and stationary rails of walking beam type of work conveyor are clearly shown

ing of alloy, and better balanced mechanisms.

Creep — Three years ago there was a lively controversy going on between two schools of thought concerning the phenomenon of "creep." When metals are stressed at high temperatures, they slowly elongate or creep. The rate of elongation rises rapidly as the unit stress is raised (the proportion is somewhere in the vicinity of the fifth power). One school had it that all metals creep at any stress no matter how low or at what temperature, provided sufficient time is allowed. The other school contended that there is a certain stress below which no movement takes place.

Experience proves that for all practical purposes the stress-of-no-creep school is right. Beams have now been in steel mill service for three years which show no visible sag between supports. This proves what one would naturally expect of the fifth power relationship — namely, that as the stress is lowered the creep rapidly approaches zero. The converse, by the way, is instructive in that long overloads (or long overheating) produce rapid failure. Overloads for short intervals do little harm.

Creep is approximately proportioned to time. Creep curves are usually steep the first few hours and then flatten out into straight lines. This is probably due to work hardening. The continued constant rate may represent the balance between progressive annealing and progressive work hardening.

Resistance to creep is also roughly proportional to grain size, castings having more strength than rolled metal.

Fundamental Motions — Where lubrication is not possible, there are only two theoretically correct mechanisms: The ball (time-honored by its use in box annealing) and the knife edge (long in use in platform scales).

The wheel turning on a shaft has not been practicable, but if the shaft is cast integrally with the wheel and the ends of the shaft are tapered, it is a satisfactory mechanism in case the load it carries is heavy in comparison with the weight of the wheel and shaft (carburizing boxes, for instance). If the load is comparatively light, as for instance a sheet of steel, the wheel does not turn. Tapered shafts are self cleaning of brick dust and dirt, and the wheel is self centering, thereby avoiding the friction of any side thrust.

Another motion (applied in 1930) is direct sliding of one member on another. One would expect that the rubbing surfaces would quickly gall, seize, and wear out, but there was no wear in an experimental unit. The high spots had work hardened to a polished surface. After two years in service (about one year of actual operation) there is still no wear visible in any of several installations.

Thus, it happens that in a situation where no lubrication is possible, nature has provided materials that can get along without it.

Composition of Alloys — There are two reasons why ordinary structural steel cannot be used at temperatures of 1400° to 1900° F.: (1) It oxidizes so rapidly that in a few days there is little metal left, and (2) its strength is not sufficient to support itself, let alone carry a load. It would wilt in a few hours.

However, if 20 or 30% of chromium is added to the steel, the resistance to oxidation is so greatly increased that it is years instead of days before the metal thickness has decreased to any extent. Also the strength at high temperatures is increased. If, in addition, 10 to 35% of nickel is added to the iron-chromium mix, the strength is still further increased so that wilting is postponed for years instead of hours.

Other elements aid the foundryman in producing sound castings. Carbon, for instance, lowers the freezing point, but it must be used sparingly (0.30 to 0.60%) because an excess makes the castings brittle at temperatures below about 500° F., although they are increasingly ductile as the temperature rises above this figure. Another aid to casting is silicon. This element improves fluidity.

The above elements have been combined in the following proportions and have produced good results: Cr 25%, Ni 19%, C 0.35%, Si 3%. Beams of this mixture have sagged not over $\frac{1}{8}$ in. in 5-ft. spans in two years of service at 1400 to 1600° F. At higher temperatures (1750 to 1850° F.) the beams have held within a 1-in. sag under similar conditions. If the flue gases bathing these castings contain above 1 or 2 grains sulphur per cu.ft. of gas, the nickel content must be down to 14%. Entirely satisfactory results have been obtained with such beams used in furnaces fired with producer and coke oven gases whose sulphur content was regarded as being fairly high.

When strength is the ruling consideration, it is generally conceded that what is commonly known in the trade as "35-15" is best (35% Ni and 15% Cr generally cast as 37-17 or higher). But, having a higher nickel content than the alloys previously mentioned, it costs more, is more susceptible to corrosive gases, and hence its use is indicated only in special cases.

The above are some basic facts. On account of the wide variety of applications, experiences, and experiments a great many contradictory statements about details have been made. Some say that silicon above 1% weakens the metal and others say it does not. Some claim that molybdenum, titanium, tungsten, and other elements confer special properties. The truth probably is that the latter are of the nature of refinements and are used by the various foundries in small quantities as the art requires.

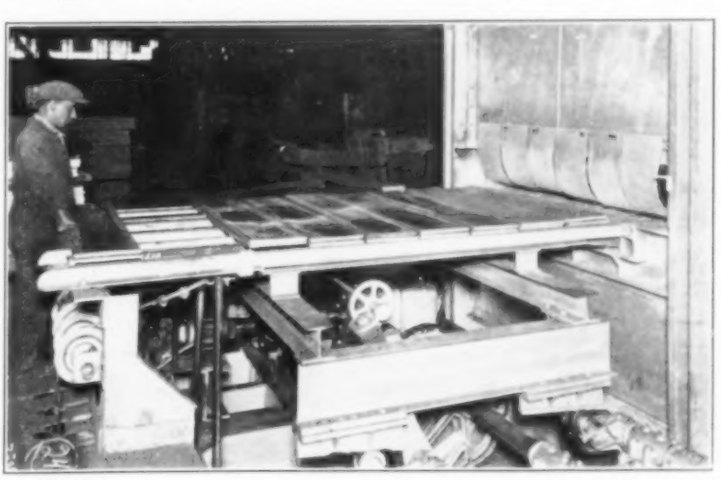
It is important to note that the different alloy foundries have developed individual practices and mixtures of their own to attain different results. Since the foundry practice has an important bearing on the performance, it is important that the alloy maker be allowed to adjust the analysis in minor elements to fit his individual experience.

Engineering Calculations

In engineering calculations the size of a furnace beam depends upon the load and its location in relation to the supports (the bending moment) and the design stress (stress in the extreme fiber. Design stress is judged from experience with the type of alloy, the probable soundness as produced by the maker of the alloy, and the probable abuse.

As a rule, the most desirable section for beams is the I-beam. When casting such beams it is customary to use a $\frac{3}{8}$-in. section for web and flanges in beams up to 8 ft. long. Occasionally smaller castings can be made with $\frac{5}{16}$-in. section. Larger castings will require up to $\frac{5}{8}$ in. metal, depending upon size and shape. The idea is to keep the sections as thin as possible

Charger End of Sheet Bar Heating Furnace With Walking Beam Conveyor Mechanism. All motions controlled from this end



for economy, but at the same time provide enough metal so that the founder can produce sound castings. (Frequently, unsoundness can be detected only by breaking a sample piece or by X-ray photographs, all of which add more cost to the casting than a little extra metal.)

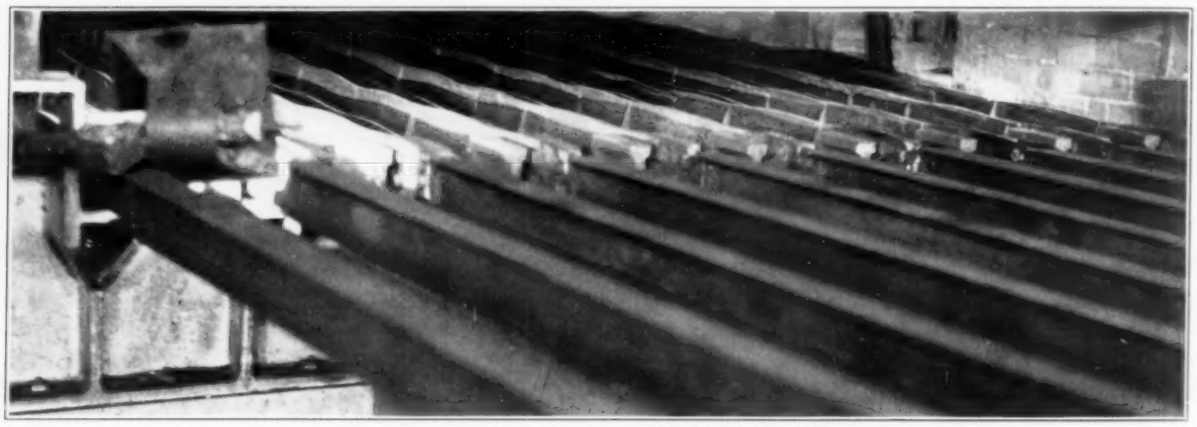
Plastic Versus Elastic Flow — Machine and structural design is based on formulas which apply to elastic materials within the elastic limit, yet furnace beams are operated at temperatures and loads where slow plastic flow occurs. Fortunately studies on plastic flow of alloys indicate that the elastic relations hold for high temperature plastic flow within the limits of accuracy of our basic creep data, and certainly within the limits of dependability of our present more or less unsound castings. Experience has indicated that a beam increases in rigidity as sag progresses — in other words, if a hot beam is overloaded it will sag at first rapidly and then more slowly. This is because the outer fibers yield or creep, putting more of the load on those nearer the neutral axis of the beam where at first they are working under low stresses.

Continuous Beams — When all factors are considered, a continuous beam is about six times as strong as a simple beam; or, to put it the other way around, a continuous beam of a given weight will carry a given load on a given span six times as many hours before it sags a given amount.

Some of the properties of a continuous beam are of interest. A continuous beam of uniform section, loading, and span may be considered to be the equivalent of combinations of simple and cantilever beams. If all were in perfect balance, hinges could be used to join the sections together at points where there would be no bending moment. In practical structures, however, irregular loading would result in a certain amount of bending moment at the hinges. Also it is convenient to avoid as many joints as possible.

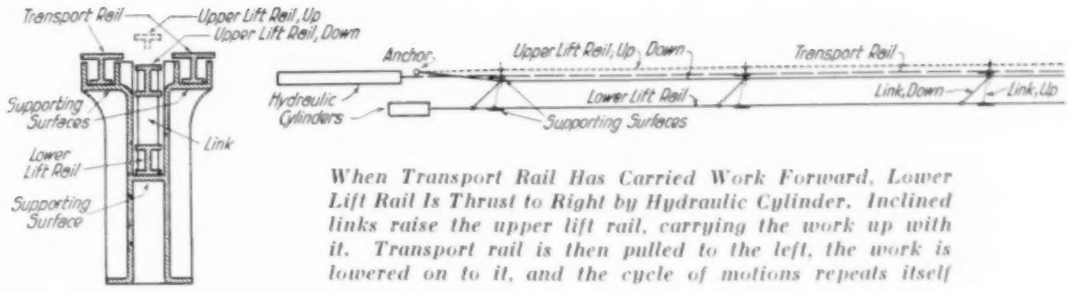
When a continuous beam slides back and forth over a point of support, it becomes more or less self-straightening. Advantage can be taken of this fact by using a somewhat higher design stress.

Another point: In cold structures, the continuous beam must be supported on firm foundations, because any settling results in relatively large unallowed-for stresses. But in the heat, a beam will quickly sag to reach any support which may become depressed, thereby retaining the internal stresses of the metal at about the original magnitude.



Stationary Rails at End of Sheet Pack Furnace. Moving rails are depressed and invisible. Stationary rails are inverted T-sections, with wavy tops. Shadows cast by light at left should not be interpreted as any structural feature

The sketch on page 49 shows a typical mechanism involving the use of continuous beams. Such a mechanism has the great practical advantage of being operated from the charge door. The vertical lifting movement involves no holes in the sides, top, nor bottom of the furnace and hence this construction avoids any possibility of air infiltration. The success of this mechanism depends largely upon the



When Transport Rail Has Carried Work Forward, Lower Lift Rail Is Thrust to Right by Hydraulic Cylinder. Inclined links raise the upper lift rail, carrying the work up with it. Transport rail is then pulled to the left, the work is lowered on to it, and the cycle of motions repeats itself

work hardening effect where rails rub on stools.

Splices — The design of splices is no mean job. One of the worst situations the designer meets in high temperature work is where a series of rails is subjected to alternate tension and compression. Any design can be greatly simplified if the beams can be kept in tension only or in compression only. If splice plates like railroad joints were put into the heat with alternating stresses, the bolts would loosen and the structure pound itself apart in short time. By taking the load off the bolts and putting it on lugs, the difficulty is overcome. Flexible splices can be made after the manner of eye-bars in bridges. Here the cross-sections are so proportioned as to have equal strength at the splices and in the beams without changing the thickness of the section. Such joints have been sound, judging by their excellent performance.

Refinements in Calculations

Some refinements of the above procedures of calculation have been attempted with more or less success. Alloys having low creep stress have been sought; mathematical studies have been made on the distribution of stresses throughout the section of an I-beam, and finally, creep-stress-temperature charts have been prepared for the designer.

But these refinements from this information are minor, and their use tedious. The fundamental data are still too meager and the effects of unsoundness in the castings are too important to warrant these corrections. Until we can get rolled or cast beams which are always as sound and, therefore, as dependable as the usual structural members in the cold, attempts at minor refinements are futile. When this happy state is reached we must then get furnace operators who can specify in advance what the temperature and loading of the mechanism are to be, and who will operate within these limits. At that time a considerable improvement in the design will be possible, with consequent savings in alloy and power.

Coefficient of Friction — In order to gage more accurately the stresses set up in such mechanisms as the one shown, some friction tests were made on beams which had been well worn under practical conditions. Also, the friction of low carbon steel on alloy rails was measured. The results were:

		Coefficient of Friction	
Materials	Temperature	Start	Steady Slide
Alloy on alloy	Cold	0.70	0.62
" " "	1600° F.	0.66	0.51
" " "	1900°	0.64	0.47
Steel on alloy	Cold	0.64	0.47
" " "	1400° F.	0.73	0.39
" " "	1900°	0.59	0.31

When using these results, it is advisable to add a factor of safety of 10% or more, depending on conditions.

Design of Castings — Alloy castings are designed on the same principles as any metal casting. Considerable care must be taken to avoid sharp turns, intersecting planes, and any other shapes which obstruct the flow of the metal. The alloys become sluggish quickly, and any impediment will act as a potential cause of local unsoundness. Long curves are preferable to sharp angles. All sections should be the same thickness wherever possible.

Fillets must be of small radius. If the radius is large a cavity will result at the center of the adjacent mass.

Design the castings with the cooperation of the foundryman, because he can give practical suggestions which improve the casting and reduce its cost. To take the foundryman completely into one's confidence pays dividends, for secrecy is costly.

By Earle B. Whittemore
Wickwire Spencer Steel Co.
Worcester, Mass.

age hardening in Strip Steel

Paper for Buffalo Convention, A.S.S.T., October, 1932. Written Discussion Invited

MANY users of strip steel have shown considerable interest in the increase in hardness and loss of ductility due to aging in basic open-hearth steel of the following composition: Carbon, 0.05 to 0.15%; manganese, 0.30 to 0.50%; phosphorus, 0.05% maximum; sulphur, 0.05% maximum; and silicon, 0.05% maximum.

Whereas most manufacturers and consumers of this type of material accept age hardening as a fact, they do not agree upon the extent of the changes. This may be due in part to a failure to mention the *temper* of the material in question and the *period* of aging.

At the outset let us define "temper." Temper of cold rolled strip steel indicates the hardness and the ductility best adapted for further work (such as blanking, forming, perforating, or drawing to shallow or deep cups and tubes). These different physical properties in low carbon basic steel (cold rolled strip) are obtained by controlling the amount of cold rolling done upon the hot rolled material or on the material in the soft or annealed state.

Tempers are designated by terms from "full hard" to "dead soft" — numerically from number one (full hard) to number five or six (dead soft for deep drawing). In more recent years Rockwell and Brinell hardness tests have been of great assistance to strip steel manufacturers in supplying material within close limits of hardness. General specifications are tabulated at the foot of the opposite page, wherein plasticity is noted as elongation in a standard tensile test piece. Ductility — so-called — is a physical property overlooked by many consumers, and may be determined by one of several ball and plunger machines which form a cup under known conditions of load and depth of draw. When he specifies a Rockwell or Brinell hardness value and a cupping or drawing test, the consumer of strip steel has made known his definite requirements.

Much has been written and said about the limits which should be written into various specifications for materials. Much of this also applies to cold rolled strip steel. The hardness range (as determined by the Rockwell method) considered by the writer to be liberal to both consumer and manufacturer for a given temper range, is about ten points on the B scale using the 100-kg. load with $\frac{1}{16}$-in. steel ball penetrator on thicknesses of 0.020 in. and heavier. Thinner sections should be tested under the 60-kg. load and the hardness range slightly reduced, whether the material is to be used for blanking, forming, perforating, or drawing by full-automatic, semi-automatic or manual feeding methods.

Although manufacturers may adhere strictly to a hardness range similar to the above, discrepancies will be noted between the hardness readings reported by the consumer upon receipt of the strip steel and the testing records of the manufacturer on the same shipment of

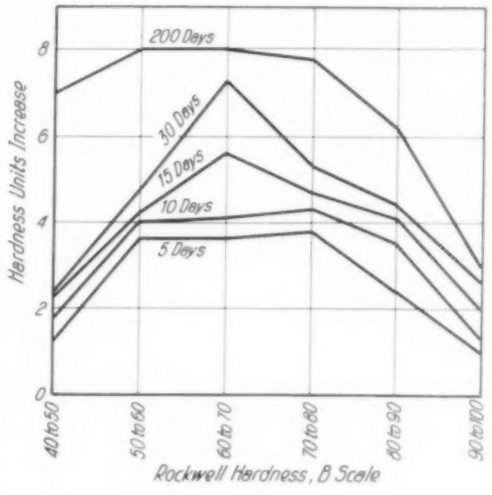
material. Incidents of this kind have brought about a more common recognition of the phenomenon of age hardening, which the writer will now attempt to present briefly for practical application by readers interested in the changing physical properties of steel of the above analysis.

Aging is a definite increase in hardness, elastic limit, and tensile strength with consequent loss in ductility or workability. It occurs during the period the steel is at rest at normal temperatures following the completion of cold work. This phenomenon has been recognized in many metals and alloys, both after quenching and after cold deformation. Many researches have been carried on, both here and abroad, to determine its causes and possible control.

The extent to which basic open-hearth steel, in the form of low carbon cold rolled strip, ages under normal conditions appears to cover a considerable period of time, although it becomes noticeable about five days after rolling is finished. The results of many tests made under standard mill conditions are assembled in a curve and a table. The curves show the average increase in Rockwell units; the data include all tests for periodic increase in hardness taken at various times during the past two years. The table at the top indicates the expected increase in Rockwell hardness units within definite periods. The samples were taken during the production of various thicknesses, and were not control samples for a laboratory investigation. This method was used to secure averages which would be applicable to general mill practices and which would not be dependent upon any particular type or method of cold rolling procedure.

AGING OF BASIC STRIP

Hardness at Time of Rolling	Expected Increase in Hardness		
	5 Days	30 Days	7 Months
B-40 to B-50	1 to 2 units	2 to 5 units	6 to 7 units
B-50 to B-60	3 to 4 units	4 to 6 units	7 to 8 units
B-60 to B-70	3 to 4 units	6 to 8 units	7 to 8 units
B-70 to B-80	3 to 4 units	4 to 6 units	7 to 8 units
B-80 to B-90	2 to 3 units	4 to 5 units	5 to 6 units
B-90 to B-100	1 to 2 units	2 to 3 units	2 to 3 units



Increase in Hardness Due to Aging of Low Carbon Strip Steel, Cold Rolled by Commercial Mill Practice

Tests on annealed material are erratic. Some aged but slightly within one month and showed a marked increase thereafter. Other annealed material followed the same general increase as medium tempers, although the increase was much slower.

The greatest amount of aging was found in tempers of a Rockwell hardness B-50 to 80; increases of some samples reached 10 to 11 points on the B scale during the seven-month period. Harder tempers, B-80 and higher, seldom hardened more than 5 or 6 points during this period of time.

Some rather interesting additional observations have been made during these tests which, although known to science for some time, have not been given general recognition. While annealed material appeared to age more slowly and with erratic results, when subjected

GENERAL SPECIFICATIONS FOR BASIC OPEN-HEARTH LOW CARBON COLD ROLLED STRIP

Temper	Rockwell Hardness	Arbitrary Temper Index	Minimum Tensile Strength lb. per sq. in.	Elongation % in 2 in.	Notes
Hard	B-90 and over	1	60,000		Flat work and easy punchings. No bends.
Half Hard	B-75 to B-90	2	55,000	Min. 5, Max. 20	Easy blanking. 90° bend across the grain.
Quarter Hard	B-60 to B-75	3	45,000	Min. 15, Max. 39	Medium soft. Bend 180° across the grain, 90° with the grain.
Soft	B-50 to B-60	4	40,000	Min. 39	Bending, forming, shallow drawing. 180° bend either way of the grain.
Deed Soft	Under B-50	5 or 6	40,000	Min. 40	Extra deep drawing quality.

to a "pinch pass" (very slight reductions of 0.0005 to 0.001 in., depending upon the thicknesses being worked) this material is subject to moderate aging. It also appears that the speed at which the aging takes place is related to the amount of cold work in reduction from the annealed condition. The rate of aging is larger in some tempers — aging requires more time for the harder tempers than for the softer tempers, and the soft and medium tempers age to a greater extent within a specified time.

Apparently, cold working in various degrees intensifies or retards the practical evidences of aging, within limited periods. If annealed strip 0.020 to 0.060 in. thick is reduced 0.002 in. by cold rolling, aging becomes more rapid and pronounced. This probably accounts for the similarity of aging in the soft and medium tempers.

If the material in the annealed state has a Rockwell hardness above B-50, the annealed hardness does not influence the aging which readily responds after cold working. Most material in these tests had an annealed hardness under Rockwell B-45 (many under B-40) which accounts for the great increase in hardness of the medium tempers after prolonged periods of rest. (All tests recorded in the B-40 to B-50 hardness range have been subjected to cold working. The hardness ranges above B-50 are developed by varying amounts of reduction by cold working.)

Several hard samples of cold rolled steel of medium and high carbon content (approximately 0.60% and 0.90% carbon) were also tested and found to age harden only to a slight degree, say 1 to 3 points, and then only after at least one month at rest.

It has been recognized for some time that age hardening may be accelerated by subjecting the material to temperatures of 200 to 600° F. For practical application, immersion in boiling water from 15 to 30 min. will indicate the extent of aging for one or two months under normal conditions of material at rest.

Several theories have been advanced by scientists to explain this phenomenon of aging. E. W. Ehn summarized them in an article entitled "Seasoning of Steel" in last September's METAL PROGRESS. Aging or seasoning is evidently a property possessed by many metallic alloys. Duralumin is a conspicuous example. Perhaps the most widely accepted explanation is known as the precipitation hardening theory, which postulates a supersaturated solution retained at room temperature from which particles gradually precipitate, causing an increase in hardness. The theory agrees with the more recent iron-carbon equilibrium diagrams, which show a slight solubility of carbide in alpha iron from room temperature to approximately 1700° F. This theory has been strengthened by investigations on hardness changes in quenched low carbon steels, although conflicting opinions exist as to whether the precipitation of small particles causes hardness, or whether hardening is due to a rearrangement of the space lattice resulting from the precipitation.

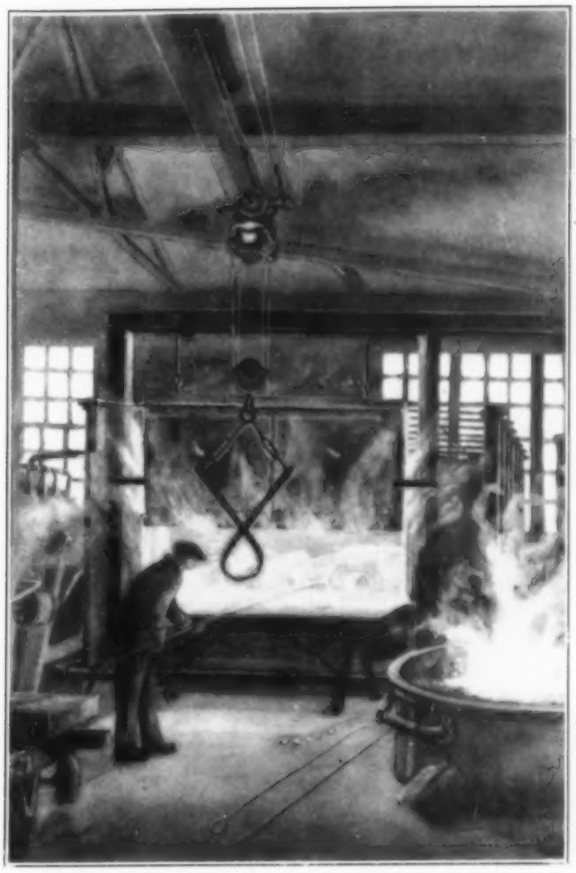
The effect of carbon on the age hardening capacity of steel has received considerable attention. Low carbon steels containing approximately 0.0025% carbon appear to age only to a negligible degree after cold working. Steels with intermediate carbon content up to 0.14% have been reported to age in varying amounts consistent with the increased carbon.

Others believe that the oxygen content, either as oxides or dissolved oxygen, has a determining influence. Developments in science appear to show that an increase in the oxygen contained in low carbon steel enlarges the area in the iron-carbon equilibrium diagram within which carbide is soluble in alpha iron. This lends further evidence to the theories of precipitation hardness.

In concluding this brief discussion of the ability of low carbon steel to change in physical properties following cold working, it should be apparent that specifications for cold rolled or cold drawn material of a carbon content under 0.15% should make allowances for aging or seasoning. With the increasing amount of information becoming available on the subject, slight changes in hardness, tensile strength, elastic limit, elongation and yield point may be determined with more accuracy. Greater recognition should be given to the changed properties of this type of material at the time of further fabrication, rather than at the time of manufacture, since the consumer usually has the most information concerning the amount of workability which this type of steel should possess.

By Charles W. Briggs
Division of Physical Metallurgy
Naval Research Laboratory
Bellevue, Anacostia, D. C.

Castings Hardened from below critical



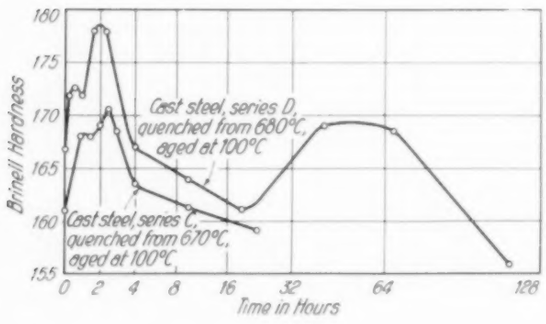
Water Color by E. D. McDonald *Courtesy of W. S. Biddle*

Paper for Buffalo Convention, A.S.S.T., October, 1932. Written discussion invited

POSSIBILITIES of age hardening as a "low internal stress heat treatment" look exceptionally encouraging when various types of intricate and complex steel castings are under consideration.

The term "low internal stress heat treatment" is used for a heat treatment *below* the critical range. The usual type of heat treatment, especially that of hardening, sets up internal stresses of various magnitudes in steel. These, of course, generally arise from the contraction and expansion of the steel traversing the critical range, because a portion of the object may quite often be contracting while another portion may be expanding. This is especially true in quench hardening. Simultaneous contraction and expansion cannot exist in a heat treating operation below the critical range, and hence the term "low stress heat treatment."

Several noteworthy textbooks, in discussing the hardening of steel, have definitely pointed out that in order to harden steel it is necessary to heat it above its critical range and then cool quickly, as any attempt at hardening by sudden cooling from a temperature inferior to its critical range would result in but a very slight, if any, increase of hardness. Just how much latitude is to be placed on the term "very slight" is rather difficult to say. Nevertheless, there is a heat treatment that involves sudden cooling from below the critical range that produces important changes in the physical properties of the steel. This heat treatment takes advantage of the phenomenon of aging or sea-



soning. The general operation is as follows:

Heat the specimen to a temperature below the critical range, preferably between 600° C. (1100° F.) and the A_1 point, and quench in water. The specimen is then allowed to age either at room temperature, or at slightly elevated temperature for a predetermined time.

No attempt will be made to go into the mechanism of aging in this article, as various investigations have given the subject considerable attention, and Mr. Whittemore's article just ahead of this one outlines the theory. Much of it still requires experimental substantiation. A useful summary was written by E. W. Ehn and published in METAL PROGRESS, September, 1931. All that is necessary to point out here is that through certain treatments the solid solubility of some of the constituents of steel is temporarily increased and upon lapse of time these constituents precipitate out of the solid solution and in so doing bring about an increase of hardness, tensile strength, and yield point, and a decrease of elongation, reduction of area, and of impact strength.

To show these effects a cast steel with the following analysis was used in the experimental work: Carbon 0.25%, manganese 0.70%, silicon 0.31%, phosphorus 0.026%, and sulphur 0.028%.

Hardness test pieces 1x1½x¾ in. were cut from the cast coupon. Only one Brinell impression was made on each specimen. Various treatments were given the specimens after which they were rough polished and the Brinell hardness again taken. Each reading or curve point is the average of ten measurements on as many samples. In order to obtain comparable Brinell readings at the outset, it was found necessary to anneal the test pieces at 900° C. (1650° F.) for 1½ hr.

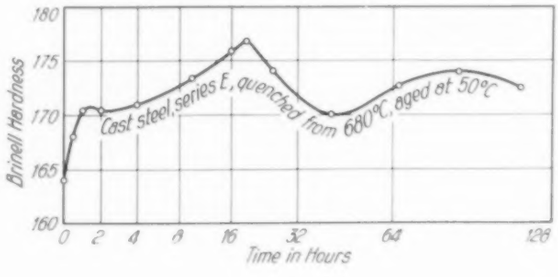
The following series of heat treatments were given these annealed pieces:

Series C. Heated for half an hour at 670° C. (1240° F.), quenched in water at room temperature, and aged at 100° C.

Series D. Heated for half an hour at 680° C. (1255° F.), quenched in water at room temperature, and aged at 100° C.

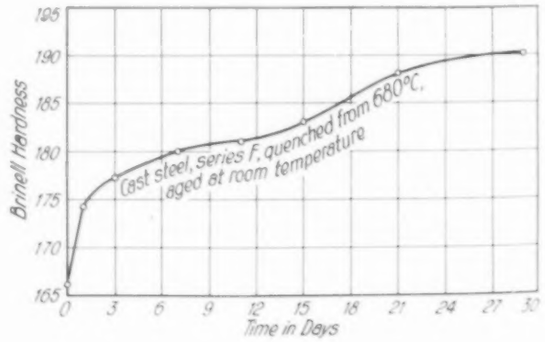
Series E. Heated for half an hour at 680° C. (1255° F.), quenched in water at room temperature, and aged at 50° C.

Series F. Heated for half an hour at 680° C. (1255° F.), quenched in water at room temperature, and allowed to age at room temperature.



The hardness after lapse of time is graphically portrayed in the figures on this page.

It will be noticed that the hardness peak comes during the second or third hour of aging at 100° C., after which there is a softening effect, followed by a secondary increase in hardness, though of a less magnitude than that obtained within the first 3 hr. A very small hump in the curve during the first hour is recorded. This feature is unexplained, as is likewise the secondary hardness fluctuation; however, these features have been prominent in all aging curves (recorded by Brinell hardness tests) that have been obtained by the Naval Re-



search Laboratory. Herbert, in England, using the pendulum hardness tester, has obtained such variations in his studies on aging.

Those quenched specimens held at 50° C. show a maximum hardness at about 20 hr., whereas those specimens allowed to rest at room temperature show a hardness maximum at about 30 days. This curve continues to rise, but it is so gradual that 30 days can be taken as the proper time to reach the maximum. One of the noticeable features is that the lower the aging temperature, the longer is the time required to reach highest hardness, and also the greater the hardness obtained.

Slight temperature variations just below the critical range produce greater hardness variations after quenching. This fact is shown well in Series C and D. Thus, in order to duplicate results, the quenching temperature must be accurately observed. Fortunately, however, the duplication of results is not so important as is the *increase* in hardness, which is comparable for individual aging temperatures.

Correct seasoning time for maximum hardness was selected from the curves and tensile test specimens prepared and treated correspondingly.

In order that the results could refer directly to the as-cast conditions, most of the 0.505-in. test pieces were machined from "as-cast" bars, and the low stress heat treatment then performed. Some low stress heat treatments were given cast bars that had been thoroughly annealed. To avoid subsidiary gassing effects, specimens were heated in a nitrogen atmosphere and water quenched. The following tests were made:

Series A. As cast.

Series B. Annealed at 900° C. (1650° F.), machined, quenched from 680° C. (1255° F.), and aged 20 hr. at 50° C. before testing.

Series G. As cast, quenched from 680° C. (1255° F.), and aged at 100° C. for 2 hr. and 4 hr.

Series H. As cast, quenched from 680° C. (1255° F.), and aged at 50° C. for 20 hr. and 48 hr.

Series J. As cast, quenched from 680° C. (1255° F.), and aged at room temperature for 21 days and 30 days respectively before testing.

TENSILE PROPERTIES OF AGED STEEL CASTINGS

Series	Treatment	Tensile Strength lb. per sq.in.	Yield Point lb. per sq.in.	Elongation in 2in.	Reduction of Area
A	As cast	77,000	41,500	21.5%	32.5%
B	Annealed at 900°C	79,000	55,000	25.5	40.2
	Annealed, quenched from 680°C and aged 20hr. at 50°C	85,500	63,000	19.7	33.1
G	Quenched at 680°C	81,000	50,000	18.0	26.1
	Quenched at 680°C and aged 2hr. at 100°C	84,000	51,000	17.5	26.1
	Quenched at 680°C and aged 4hr. at 100°C	80,750	50,000	19.5	34.7
H	Quenched at 680°C	81,500	50,000	17.4	25.8
	Quenched at 680°C and aged 20 hr. at 50°C	88,400	65,000	15.0	18.1
	Quenched at 680°C and aged 48hr. at 50°C	85,500	63,000	15.5	24.1
J	Quenched at 680°C	81,750	51,000	18.3	28.2
	Quenched at 680°C and aged 21 days at room temp.	87,500	67,000	16.5	20.0
	Quenched at 680°C and aged 30 days at room temp.	90,500	70,500	17.0	21.6

The above table lists the results.

Low stress heat treatment gives better elongation and reduction in annealed cast steel than in steel as cast. It is likewise verified that aging at room temperature produces the greatest tensile strength, with an increase of 13,000 lb. per sq.in. above the as-cast value (compare Series A and J). The yield point increased even more, 29,000 lb. per sq.in.

Accelerate Seasoning Carefully

In carrying out heat treating of this type, the aging temperature must be carefully controlled; this can be seen by the fact that by increasing the temperature from 50° C. to 100° C., the best time drops from 20 hr. to 2 hr., while raising the temperature from 20° C. to 50° C. decreases the time from 30 days to 20 hr. At 200° C. the hardness peak is reached in a few minutes.

It was thought that perhaps the physical properties might change after a long period of time even though the aging peak had been reached. For example, after seasoning at 50° C. for 20 hr. there was a possibility that the hardness might increase after a long stand at

room temperature so as to approach conditions as obtained by simply resting at room temperature. Or again, having reached the maximum hardness at 20 hr. at 50° C., there was the possibility that the specimen might soften if it were allowed to stand at room temperature. To answer these questions, specimens after aging were allowed to stand six months. Hardness readings were again taken; there were no changes in Brinell hardness. In other words, the physical properties obtained from the aging treatment are permanent.

Avoids Hardening Cracks

Low stress heat treatment can be readily applied to very irregular and intricate castings where the expansion and contraction obtained on heat treatment may result in serious injury. While this might be obvious to most, the reason is clearly seen in a typical dilation curve of a low carbon steel, copied from Publow, Heath and Batchelor's Bulletin 41, "Observations on the Dilation of Several Common Steels," Michigan Engineering Experiment Station and printed at the foot of this page. In a normal hardening operation, the cast steel object expands uniformly until it reaches the critical temperature at which point the metal contracts; then follows a period of arrested contraction and then more contraction at the A_1 point. Subsequent expansion is approximately uniform to the temperature of 900° C. (1650° F.) and even to higher heats.

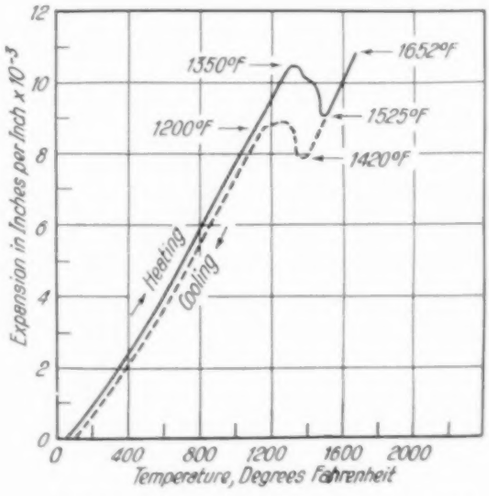
Upon quenching from this temperature, the metal must contract to the Ar_1 point, expand to the Ar_1 point, and then contract to room temperature. Since rapidly cooling castings are not uniform in temperature, one portion may be contracting, and another portion nearby contracting at a different rate, while still another portion is expanding. Under such circumstances, stresses of such magnitudes are set up within the casting that it may crack.

If, however, we quench from *below* the critical temperature, no expansion can occur, the contraction rates are practically uniform and the resulting stresses are ordinarily of minor importance.

If more elongation and contraction are required in an intricate casting than will be found in it as it leaves the mold, it should first be annealed. The heating and cooling should both be slow in order that there may be no temperature gradient throughout the casting while in the neighborhood of the critical range. Thus we eliminate possible stresses arising from nonuniform contraction and expansion at 1200 to 1500° F. Castings so treated will not have as high a tensile strength as the casting that received only the low stress treatment, but the elongation and contraction will be more improved. These facts are contained in the experimental data; compare Series B with Series H in the table.

It would be definitely better to anneal previous to the low stress heat treatment if possible, as the dendritic structure would then recrystallize. Sometimes this cannot be done; an intricate casting might warp, and the uneven heating even of good practice might be detrimental.

Enough has been said to prove that important changes in the physical properties of steel can be obtained by a low internal stress heat treatment, which involves quenching from below the critical range followed by subsequent aging. Such a low stress heat treatment permits intricate castings to be treated which would otherwise fail by normal quenching (and possibly even by a normalizing treatment) because of unavoidable contraction and expansion stresses.



Low Carbon Steel Contracts While Being Heated Through the Critical Range; Expansion on Cooling Is Somewhat Delayed

Heat Treating of Steel

Monday, Oct. 3, 10 A. M.

Observations on the Effect of Normalizing Medium Manganese Steels on the Microstructure and Physical Properties—C. R. Austin, Westinghouse Electric & Mfg. Co., East Pittsburgh.

The Scaling of Steel at Heat Treating Temperatures—Clair Upthegrove and D. W. Murphy, University of Michigan, Ann Arbor.

A Low Internal Stress Heat Treatment—C. W. Briggs, U. S. Naval Research Laboratory, Bellevue, Anacostia, D. C.

Deep Etch Testing

Monday, 2:30 P. M.

Development and Application of Macro-etching—H. G. Keshian, Chase Companies, Waterbury, Conn.

Preparation of Specimens For Deep Etching, Etching Reagents, Time and Temperature of Etching—M. Yatsevitch, Watertown Arsenal, Watertown, Mass.

Routine Disk Inspection in Quality Steel Manufacture—G. V. Luerssen, Carpenter Steel Co., Reading, Pa.

An Interpretation of the Deep Acid Etch Test as Applied to Tool Steels—J. P. Gill and H. G. Johnstin, Vanadium Alloys Steel Co., Latrobe, Pa.

Research

Tuesday, Oct. 4, 10 A. M.

Transformation in the Carbide Phase During Graphitization—H. A. Schwartz, National Malleable & Steel Castings Co., Kent R. Van Horn, Aluminum Co. of America and C. H. Junge, National Malleable & Steel Castings Co., Cleveland.

The Role of Nickel in Nitriding Steels—H. J. French, The International Nickel Co., New York City, and V. O. Homerberg, Massachusetts Institute of Technology, Cambridge, Mass.

Creep Characteristics of Metals at Elevated Temperatures—A. E. White and C. L. Clark, University of Michigan, Ann Arbor.

Drop Forging

Tuesday, 2:30 P. M.

Further Experiments on the Forgeability of Steel—O. W. Ellis, Ontario Research Foundation, Toronto, Canada.

Behavior of Steel in Sulphur-Containing Atmospheres at Forging Temperatures—D. W. Murphy, University of Michigan, Ann Arbor.

Heating Steel For Forging—R. E. Waldron, Dominion Forge & Stamping Co., Walkerville, Ontario, and N. L. Deuble, Republic Steel Corp., Massillon, Ohio.

Drop Forging Practice—Adam M. Steever, Great Lakes Forge Co., Chicago.

Annual Meeting and Campbell Memorial Lecture

Wednesday, Oct. 5, 10 A. M.

Factors Affecting the Inherent Hardenability of Steel—Edgar C. Bain, Metallurgist, Research Laboratories, U. S. Steel Corp., Kearny, N. J.

Sheet and Strip Steel

Wednesday, 2:30 P. M.

Factors Influencing the Annealing of Cold Rolled Strip Steel—G. R. Brophy and L. L. Wyman, General Electric Co., Schenectady.

Autographic Stress-Strain Curves of Deep Drawing Sheets—Reid L. Kenyon and Robert S. Burns, American Rolling Mill Co., Middletown, Ohio.

Principles of Lubrication in Cold Drawing Sheet Steel—H. A. Montgomery, H. A. Montgomery Co., Detroit.

Age Hardening in Low Carbon Strip Steel—Earle B. Whittemore, Wickwire Spencer Steel Co., Worcester, Mass.

High Speed Steels

Thursday, Oct. 6, 10 A. M.

The Cobalt-Tungsten System—W. P. Sykes, General Electric Co., Cleveland.

Thursday Morning, Continued

THE TEMPERATURE ATMOSPHERE PROBLEM IN HIGH SPEED STEEL—Sam Tour, Lucius Pitkin, Inc., New York City.

SOME MOLYBDENUM HIGH SPEED STEELS—J. V. Emmons, Cleveland Twist Drill Co., Cleveland.

Research

Thursday, 2:30 P. M.

ALLOTROPY IN IRON AND STEEL—R. H. Harrington, General Electric Co., Schenectady, N. Y., and Wm. P. Wood, University of Michigan.

THE HARDENING TRANSFORMATION IN MANGANESE STEELS—Howard Scott and J. G. Hoop, Westinghouse Electric & Mfg. Co., East Pittsburgh.

Research

Friday, Oct. 7, 10 A. M.

A SIMPLE CUTTING TOOL FOR MEASURING PRESSURES IN THE DIRECTION OF CUT—O. W. Boston and C. E. Kraus, University of Michigan.

ALLOYS OF IRON, MANGANESE AND CARBON—Francis M. Walters, Cyril Wells, John F. Eckel and V. N. Krivobok, Carnegie Institute of Technology, Pittsburgh.

INTERNAL FRICTION IN IRON AND IRON ALLOYS—Robert S. Canfield, U. S. Naval Research Laboratory, Bellevue, Anacostia, D. C.

Corrosion Resisting Steels

Friday, 2:30 P. M.

THE MANUFACTURE OF STAINLESS STEELS—E. R. Johnson and R. Sergeson, Republic Steel Corp.

DESIGN OF HEAT RESISTING ALLOY MEMBERS AND THEIR PERFORMANCE IN THE FIELD—Ralf S. Cochran, Surface Combustion Co., Toledo, Ohio.

CORROSION RESISTANCE OF IRON-CHROMIUM ALLOYS IN VARIOUS MEDIA; THE SALT SPRAY TEST—Wm. B. Arness and J. N. Ostrofsky, Alloy Research Corp., Baltimore, Md.

COMBINED PROGRAM, NATIONAL METAL CONGRESS

Monday, Oct. 3	Tuesday, Oct. 4	Wednesday, Oct. 5	Thursday, Oct. 6	Friday, Oct. 7
Morning Sessions				
A. S. S. T. Heat Treating	A. S. S. T. Research	A. S. S. T. Annual Meeting and Campbell Memorial Lecture	A. S. S. T. High Speed Steel	A. S. S. T. Research
	Welding Society Non-Ferrous Metals	Welding Society Merchandizing	Welding Society Welding Technique	Welding Society Inspection Trips
Automotive Engineers Tools		Drop Forging Institute Trade Associations	Institute of Metals Brass and Bronze	
	Wire Association Material Handling	Wire Association Copper Wire	Wire Association Patenting	Wire Association Annual Meeting
A. S. M. E. & S. A. E. Joint Luncheon			A. I. M. E. Divisions Executive Luncheon	
Afternoon Events				
National Metal Exposition Open Noon to 10 p.m.	National Metal Exposition Open Noon to 10 p.m.	National Metal Exposition Open Noon to 10 p.m.	National Metal Exposition Open Noon to 6 p.m.	National Metal Exposition Open Noon to 10 p.m.
A. S. S. T. Deep Etch	A. S. S. T. & Drop Forging Institute	A. S. S. T. Sheet and Strip	A. S. S. T. Research	A. S. S. T. Corrosion Resisting Steels
Mechanical Engineers Machine Tools		Institute of Metals Copper	Institute of Metals Annual Lecture	
		A. I. M. E. (Iron & Steel Division) Inclusions	A. I. M. E. (Iron & Steel Division) Research	
Welding Society Cutting	Welding Society Research	Welding Society Welders' Qualifications	Welding Society Pressure Vessels	
	Wire Association Management	Wire Association Rubber Covered Wire	Wire Association Stainless Steel	
Evening Meetings and Dinners				
Mechanical Engineers Grinding and Cutting		A. I. M. E. Divisions Joint Dinner	A. S. S. T. Annual Dinner	
Welding Society Directors' Dinner		Welding Society Dinner		

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THE telephone is something more than an instrument to carry your voice across the miles. It is a most important member of your family.

Faithfully, constantly, cheerfully it serves you. Keeps you in touch with friends. Stands guardian over your home. Helps to put more pleasure and achievement into life and living. And does it all so capably.

When you are moving, you keep your telephone in the old home until the last van has gone and you place the key in the lock for the final turn. You arrange in advance to have a telephone ready at the new address so there will be no break in your contact with the world. When a young couple starts housekeeping. When there is illness in the home. When somebody goes away. When distances are great. When emergencies arise. On all of these occasions the telephone earns its right to family membership.

Day or night, any part of the telephone company's army of skilled workers, intricate equipment, and millions of miles of wire is at your command.

It is the Bell System's constant endeavor to make the telephone worth more and more to every subscriber.

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from recent literature

PRESS forging of the new Ford front axles requires only 2.6 min. as compared to 10 min. for each end with hammer forging; production of connecting rods has been increased 147% by restriking in a press instead of with a hammer. Another innovation in the production of the new Fords is the introduction of **CONTINUOUS FORGING**, as described by E. F. Ross in the July 18th and August 1st issues of *Steel*. Front axles are made from die-rolled billets with I-beam center section and solid ends for spindle bearing supports. These are heated on the ends only to 2200° F. by passing through a continuous gas-fired furnace with chain conveyor in the center and heating chambers on either side. Two operators remove the heated billets from the furnace and place them under an 1800-ton press which, with a single stroke, forms the spindle bearings on both ends. The axles are flash trimmed, carried on overhead conveyors to electric heat treating furnaces, and pickled in the production line, using conveyor-type pickling units in which acid fumes are completely eliminated by means of water seals at either end. Forging of Ford rear axle shafts is completely automatic from the charging of the furnace to the discharge of the axles from the forging machine. Electric conveyor furnaces are used in which the billets are held vertically by means of two chains so that 8 in. of the upper end of the shaft is heated to 2200° F. during the 10 min. it takes the billet

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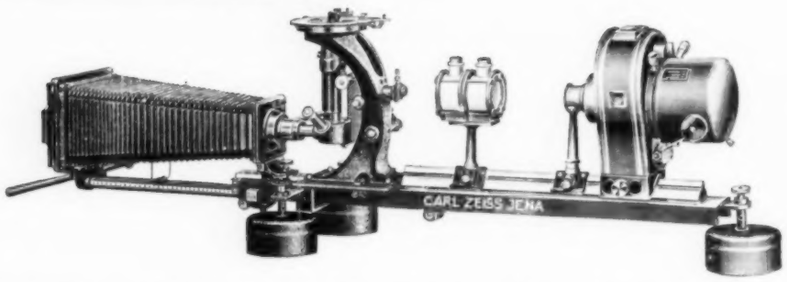
6½ x 8½



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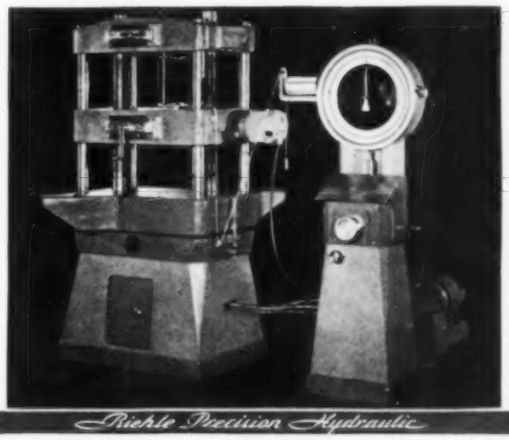
to travel the length of the heating chamber and back. The shafts are automatically cleaned free of scale, dropped into a socket, gripped by mechanical tongs, and charged into the forging machine where the gear blanks are formed in four successive impressions. The furnace and forging machine are so synchronized that each has a production of 1500 forgings per hr. Each time a heated piece is discharged from the furnace, a piece enters the machine and a finished forging is discharged.

CORROSION in oil-cracking equipment is due chiefly to the formation of hydrogen sulphide. Materials to withstand this action were discussed by J. C. Morrell and G. Egloff in May *Industrial and Engineering Chemistry* and again in July *Metallurgia*. The use of alkaline chemicals has not proved satisfactory to combat OIL REFINERY CORROSION, nor have sprayed metallic coatings or metal plating such as chromium. Cement linings, referred to as ganister and non-metallic, have been applied successfully to some installations in the field. Vessels made entirely of chromium or chromium-nickel steel would be satisfactory but are too expensive. Equipment lined with these alloys in the form of 12-gage sheet, has given good service over a period of two years without visible signs of corrosion, whereas plain steel vessels have corroded at the rate of about 0.18 in. of metal per year. An 18% chromium steel is preferable to 18-8 for linings, because it is cheaper and has a coefficient of expansion very close to that of carbon steel. The lining is welded to the steel plate before the vessel is fabricated.

AN attractive finish for such things as radio cabinets, clocks, lamps, and automobile parts is known as "PEARL ESSENCE FINISH." It has an iridescent gloss giving an effect of depth, is obtainable in any color, and can be applied to metal as well as to wood and plastics. Its manufacture from crystalline guanin obtained from the fatty layer attached to fish scales is described by D. W. Leys in *Autobody Trimmer and Painter* for May. The crystalloids are removed from the scales by churning with special detersive agents *(Continued on Page 64)*



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• That time has passed! And most of us know it. Most of us now know that "Made in U. S. A.," on any product, stamps that product as one of the finest that can be made. American brains and American ability have come into their own.

• Particularly is this true of American made precision instruments and machines. And more particularly is it true when—"by Riehle" follows "Made in U. S. A."

• Riehle built the first testing machine "Made in U. S. A." It's a far cry from that simple piece of mechanism to the Riehle Precision Hydraulic Universal Testing Machine of today—but the same pioneering spirit prompted both. And today the Precision Hydraulic is as great an advance as was the first Riehle machine in its day.

• "Made in U. S. A."—by Riehle, means much to the man or company contemplating the purchase of physical testing equipment.

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TESTING MACHINE COMPANY
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Where Specifications do not reach

The manufacture of alloy steel to render the highest possible satisfaction under a certain set of conditions involves much more than adherence to specifications. There are many factors having a great influence on behavior under operations in your plant and on performance in service that are not and cannot be covered by specifications.

In this field of intangibles lying beyond specifications, the close contact maintained by Bethlehem metallurgists between the customer and the plant is of great value. The men responsible for the control of the processes of manufacture are thus able to guide each operation with an eye to the requirements of the buyer, and the steel turned out is just the steel for the task.

Be sure to see The BETHLEHEM EXHIBIT at The NATIONAL METAL EXPOSITION

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HERE at last is a stainless alloy steel where every atom of chromium does its bit — a balanced homogenous alloy — not a mere mechanical mixture.

Every particle of chromium gives of its best in the fierce struggle to combat corrosion.

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Nevastain RA grinds, polishes and buffs easily, with a beautiful blue white finish having the high lustre of chrome plate.

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CHAR PRODUCTS COMPANY
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(Cont. from Page 61) and are further purified and partially dehydrated in centrifugal separators. Incorporation of this highly concentrated pearl essence (200 lb. of scales makes 1 lb. of essence) into lacquer is described by W. J. Miskella in July *Metal Cleaning and Finishing*. Pearl essence finishing is done in practically the same way as ordinary lacquering except that the air pressure should be about 20% lower and the gun held 12 to 14 in. instead of 8 to 10 in. from the work, since it must be sprayed fairly dry. Preliminary color coats either may be polished or left with the pebbly surface as sprayed, depending on the finish desired. Four to eight coats of essence are applied, care being taken to see that each coat is perfectly dried.

A 1200x308-ft. hangar for naval dirigibles is now being built at Sunnyvale, Cal. for the U. S. Navy. In general, it is similar to the one at Akron, Ohio, where the ships are built. Mezannine **WELDED FLOORS**, 28 ft. wide, extend the complete length of the building. According to C. A. Handschin, writing in *Western Machinery World* for July, these are of "battle-deck" construction; $\frac{3}{16}$-in. plates, 24 in. wide are laid so their edges butt over the center line of 3-in. I-beam joists. The $\frac{1}{4}$-in. gap is arc welded by hand with fluxed electrodes, and the surplus metal later ground off by a portable motor-driven grinder. End joints between plates are welded with tacked-on butt-strap underneath. All 3-in. beams are also welded to 20-in. cross-beams spaced 10 ft. on centers. In all about 8 miles of joint is to be welded, requiring $7\frac{1}{2}$ tons of welding wire.

ROUGHENING a metal surface will increase the adhesion of electroplates, but not because of any keying or locking action. M. de-Kay Thompson in July *Metal Cleaning and Finishing* points out that rulings as fine as a diffraction grating, so fine they cannot be seen with unaided eye, are 10,000 times as wide as an atom. Depositing metal atom by atom on an ordinary ground surface *(Cont. on Page 68)*

MAINTAINED *between* TOOL GRINDS

Sunoco will protect the finished work from rust and corrosion, is perfect in its emulsion; will not separate. It is hygienic and will not become rancid after prolonged use.

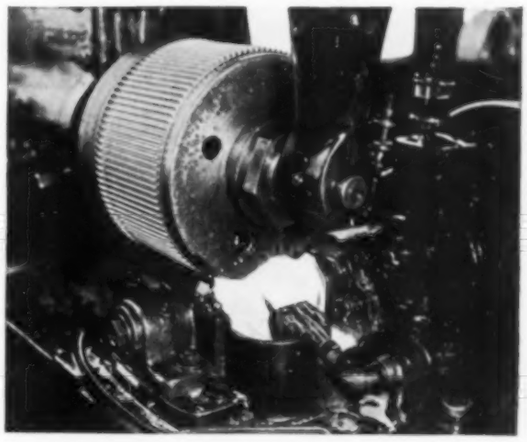
These are the reasons why leaders in the metal cutting industry recognize the value of Sunoco in producing better work at increased output per machine unit.

The Sun Oil Company offers assistance in solving individual metal cutting problems through the services of Cutting Oil Engineers who have had wide experience in the study of cutting oils and their application.

Write any of our many branches, or to our home office.

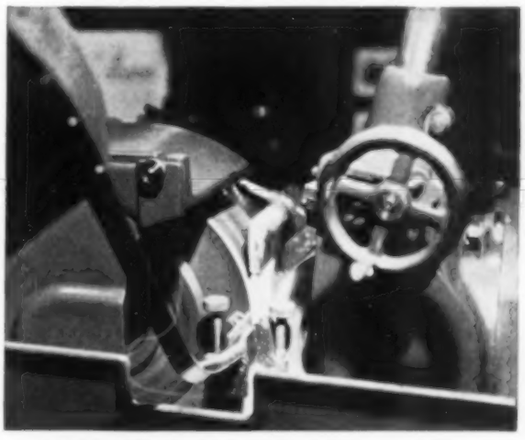
The Sun Oil Company produces a type of cutting oil to meet every metal cutting requirement.

Courtesy of The Springfield Manufacturing Company, Springfield, Ohio



OPERATION: HOBBING "EXCELSIOR" FLYWHEEL STARTER GEARS.
MACHINE: BROWN & SHARPE NO. 34 HOBBING MACHINE.
MATERIAL: .50-60 CARBON STEEL.
GEAR: 8-10 PITCH .225 IN. DEEP.
CUTTER SPEED: 120 R.P.M.
FEED: .090 IN. PER REVOLUTION OF WORK.
LUBRICANT: 1 PART SUNOCO TO 10 PARTS WATER.

Courtesy of Cincinnati Grinders, Inc., Cincinnati, Ohio



PART NAME: PISTON PIN.
MACHINE: CINCINNATI CENTERLESS GRINDER.
MATERIAL: HARDENED STEEL.
LIMITS:
ROUND WITHIN . . . . . .00005 IN.
STRAIGHT . . . . . .00005 IN.
SIZE . . . . . .0001 IN.
STOCK REMOVED: .001 IN.
PRODUCTION RATE: 28 PER MINUTE.
LUBRICANT: 1 PART SUNOCO TO 40 PARTS WATER.

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Ferro-Titanium 25%
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- GREATER UNIFORMITY
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than have ever heretofore been obtainable. . . . Don't fail to visit us at the Exposition in Buffalo to see and let us tell you about this new development. . . . If you do not attend the Exposition write for descriptive literature just issued.

AMERICAN GAS FURNACE CO.
ELIZABETH, NEW JERSEY

concentrates

(Continued from Page 69) are lapped then then cleaned in sawdust. All rolls are tested for hardness; the double draw has reduced the hardness no more than 2 points. Samples are examined under a microscope at 25 diameters for surface scratches. Diameters are checked by snap gages to ± 0.0001 in.

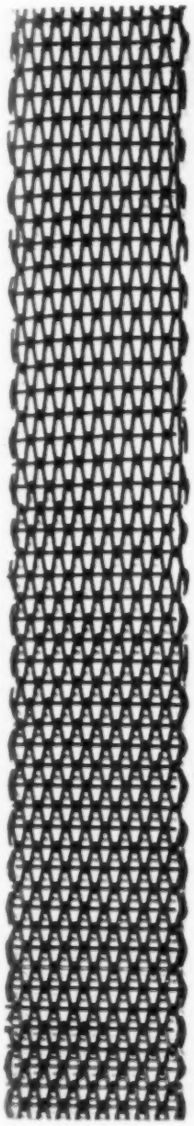
CONTINUATION of N. P. Bailey's studies on the accuracy of thermocouples (noted in these columns last December) is printed in August *Mechanical Engineering*. He welded 28-gage constantan wires to both sides of a ¼-in. wrought iron plate, heated from one side by a flat spiral of resistance wire. Theoretically, at a mean temperature of 309° F. the temperature of the hot side should be no more than 0.12° F. higher than the cool side. His two **THERMOCOUPLES** registered 312 and 306° F. respectively, showing the effect of conduction of heat away from the hot junction. Loss from this cause was 1½% over a fairly wide range of temperatures. 20-gage wires registered 1½% low. Mercury thermometers plastered to the hot surface by ⅜-in. thickness of asbestos paste registered 8% low. It has already been found by others that if two wires of a small thermocouple are peened into adjacent holes in a metal surface, the errors due to surface films are eliminated. If they are then insulated and carried away in small grooves cut in the metal surface, the error due to conduction along the wire is eliminated.

FIFTY-FIVE thousand tons of 1¾ to 2⅞-in. plate will be **WELDED** into **PENSTOCK LININGS** for the Hoover Dam by Babcock & Wilcox Co. According to *Engineering News-Record*, July 21, these pipes will range from 8½ to 30 ft. in diameter, and will carry water at about 580 ft. head. Working stresses in the steel are computed at 19,000 lb. per sq.in., and three plates 12x35 ft. in area (the largest now available) will be needed to make a single ring of the 30-ft. pipe, 12 ft. long. Two of these will be welded in the shop *(Continued on Page 76)*

WISSCO STRAIGHT-ROD REINFORCEMENT

(patented)

makes the difference



No contraction in width
20% elongation

The belts shown in photographs on both right and left were woven in the same mesh from the same wire. The only difference was the presence of the Straight-Rod Reinforcement in the left hand belt and its absence in the right hand belt. Both belts were photographed after the same period of work in 1800° F. The reinforced belt carried twice the load of the other. Note the distortion of the belt that did not have the advantage of the reinforcement. Straight-Rod Reinforcement is only one of the many patented features that make Wissco Metal Conveyor Belts the most economical belts to use for extreme temperatures, unusual chemical conditions, abrasive loads or ordinary service.

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28% contraction in width
37% elongation

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I would be pleased to receive one of your new Handbooks on Metal Conveyor Belts.

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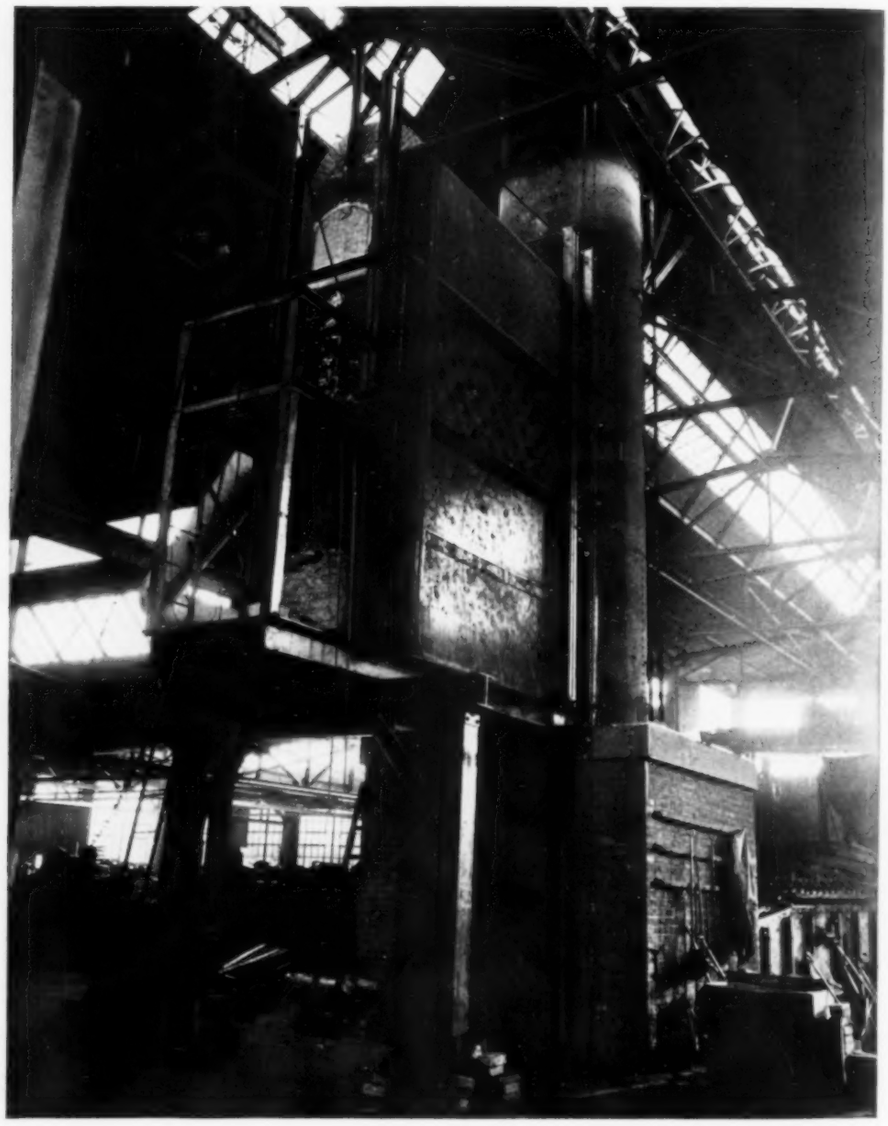
SURELY YOU ARE INTERESTED
in another Outstanding Performance-



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on a Malleable Iron Air Furnace

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—a fuel saving of 22% or a saving of 200 pounds of coal per ton of iron melted.
—reduction in time of heats.
—an improvement in the characteristics of metal tapped.
—greatly improved general combustion conditions.
—rapid rise of air temperature after firing is begun.
—the ability to handle the 2500 deg. Fahr. inlet gasses.
—a complete effective demonstration of the economy and the practicability of The Carborundum Company Recuperator.

Much of the success of the recuperator is due to the employment of tubes of "Carbofrax"—the Carborundum Brand Silicon Carbide Refractory.

These tubes have a high heat conductivity—eight to ten times that of fireclay refractories.

Core busters in the tubes greatly facilitate the transfer of heat from waste gas to air.

The "Carbofrax" tubes maintain their refractoriness and physical strength even at the highest temperature encountered in industrial furnaces.

Long life of the tubes—their resistance to corrosive action—the absence of moving parts—the design of the recuperator—its low maintenance cost—its adaptability to practically all types of industrial furnaces—particularly those requiring high flame temperature—these are some of its decided advantages.

And the cost is far less than you probably believe.

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TOOL STEEL

CLARITE HIGH SPEED STEEL
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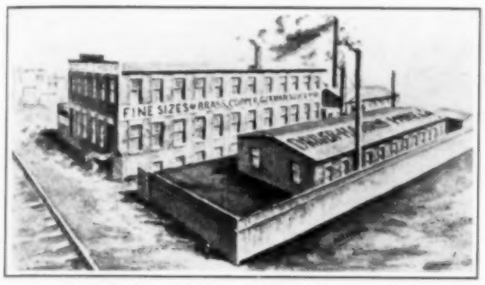
concentrates

(Cont. from Page 72) into a section 24 ft. long, given a stress-relieving anneal, and this unit, weighing 150 tons, will be delivered to the tunnel by a cableway spanning the canyon. All pipe larger than 13 ft. will be made in a plant to be erected at the site; fabrication is to be according to the A.S.M.E. code for unfired pressure vessels. Welding must be done "with automatic apparatus by a process that will exclude air from the molten metal. Each deposited layer must be thoroughly peened." The entire length of each welded joint, whether made in the shop or in the tunnel, must be inspected by X-rays. One test specimen must be made for each 12-ft. length of pipe and it must show 100% efficiency in the tension test. Girth seams in the tunnel "may be welded and strain relieved, or double-pinned outside butt straps may be used, cold-pinned for plates 1 in. and thicker." Work must start by Aug. 15, and all pipe must be installed before March, 1938.

EXTENSIVE experimentation on thick-walled pump cylinders for operation at pressures up to 1500 lb. per sq.in. showed that **LOW CARBON CAST IRON** was the best, according to H. H. Judson in *Iron Age*, July 21. To control this element more closely than by adding steel to the cupola charge, metal from two cupolas is mixed in known proportions. In one cupola soft gray iron is melted (2.40% Si, 3.50% C). In the other the charge is 1400 lb. steel rails, 135 lb. 15% Si pig, 20% spiegeleisen, and 180 lb. coke splits. Tuyeres are 8 in. above the sand bottom, and the coke bed is 34 in. above top of tuyeres (higher coke bed means more carbon pick-up). After the coke bed is burning well, the cupola is filled by hand and stands 75 min. with tuyere covers open for strong natural draft. White hot iron then appears in 5 to 6 min. after restarting the blast, and is tapped continuously. It contains about 2.5% carbon. 7500 lb. of it, mixed with 2000 lb. soft iron, gives metal containing 2.0% graphitic carbon, 0.75% combined carbon, 1.70% silicon. It is poured at about 2775 F. Tensile test bars taken through the 2¼-in. wall of a 2300-lb. *(Continued on Page 80)*

1899-1910



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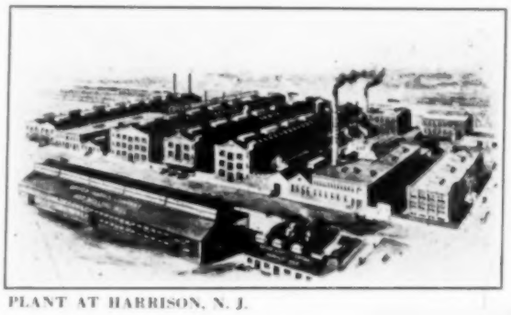

PLANT AT HARRISON, N. J.

PLANT AT MORRISTOWN, N. J.

PLANT AT MANCHESTER, ENGLAND

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for heat-resisting alloys

and

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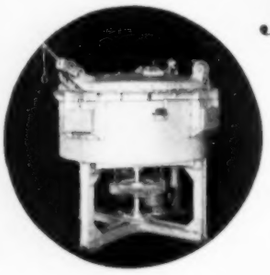


We believe that many manufacturers now using the batch method will not only improve the average quality of finished products, but will actually save money by using this rotary hearth furnace.

Individual heating of each piece; no loss of time through constant charging and discharging with steady working conditions for the operative; better control—these are some advantages. Others become apparent quickly when you read catalog No. 322C. Write for a copy.

W. S. ROCKWELL COMPANY

Industrial Heating Equipment

50 CHURCH ST., NEW YORK

Chicago Cleveland Columbus Indianapolis Detroit Montreal Toronto

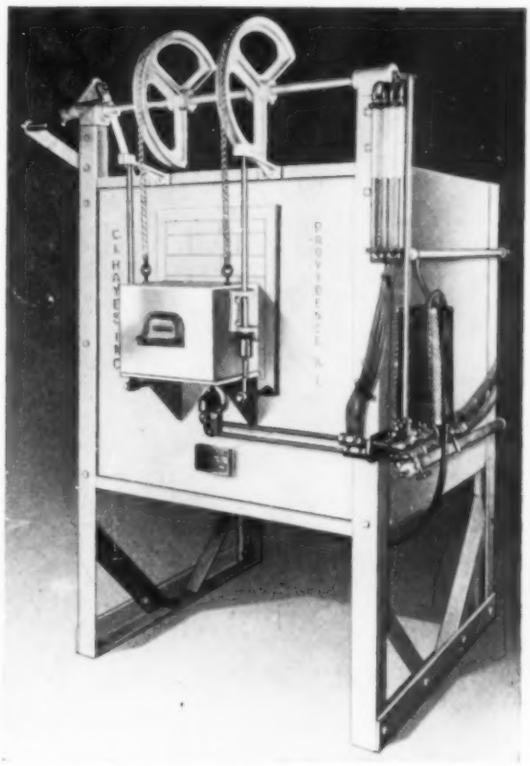
concentrates

(Cont. from Page 76) cylinder casting had a tensile strength of 46,500 lb. per sq.in., Brinell hardness of 212. The bore of the cylinder was 5¾ in.; it was oil-tight at 3500 lb., and burst at 6000 lb. pressure. In order to avoid spongy spots on top of castings, to reduce shrinkage generally, and to increase the "molten life", the blast is controlled to a volume that prevents oxidation of the cupola iron.

TESTS indicating that light-weight gas cylinders of alloy steel can successfully withstand high pressures and rough handling are described by F. S. Marsh in a paper to be presented before the British Iron & Steel Institute on Oct. 15. Two analyses of Ni-Cr-Mo steel were used to manufacture 19 experimental **GAS CYLINDERS** 30 to 35 in. long and 7.5 in. inside diameter, with 0.2-in. walls. Hydraulic pressure tests, in which the cylinders were filled with water and pressure increased in stages of 500 lb. per sq.in., showed a slight permanent set commencing at 3000 to 4000 lb. per sq.in. Bursting pressure was 6700 to 6800 lb. per sq.in., the cylinders bulging and breaking without fragmentation. Mechanical tests showed a slight increase in yield point and decrease in elongation and impact values after bursting. Three of the cylinders were charged with air to a pressure of 3000 lb. per sq.in. Two were dropped from a height of 30 ft. onto a concrete block without noticeable damage. A 56-lb. weight was dropped on the third and made only a 3 16-in. depression. Crushing and flattening tests showed uniform properties.

WITH the acceptance by the A.S.M.E. Boiler Code Committee of fusion welding for all classes of pressure vessels, considerable attention has been paid to the problem of **ANNEALING FOR STRESS RELIEF** in welded joints. The contraction upon cooling of each successive layer in a welded joint tends to narrow the groove being filled, thus warping the two plates if they are free to bend. Welded drums are not free to bend and *(Continued on Page 88)*

Cleveland Cutter & Reamer Company says:



- ✓ *"Tool spoilage entirely eliminated."*
- ✓ *"Hardening production increased 20% to 50%."*
- ✓ *"Tolerance kept within tenths of one thousandth."*
- ✓ *"More uniform Rockwell hardness."*
- ✓ *"Less grain growth."*

U. S. Patents 1,724,583; 1,851,831; 1,849,714; 1,808,721. Canadian and foreign patents issued and pending.

"—since installing our 'Certain Curtain' Furnaces!"

FIRMS who make tools of high speed and alloy steels now definitely recognize there are ***three*** absolute essentials in precision hardening.

1. *Precision control of temperature.*
2. *Accurate timing.*
3. *100% control of furnace atmosphere.*

It is in the last of these, the perfect control of atmosphere, that the Certain Curtain Furnace has demonstrated such outstanding superiority. The improvements in hardening produced for the Cleveland Cutter & Reamer Company are only one example among scores that can be quoted from the users' own words: "Records show life of tools increased one-third", says a railroad. "Tools are free from distortion", says a tool firm. "Definite improvement in productive life of tools", reports a machinery manufacturer. "Possible to hold tools at critical longer without danger of scaling, fusing of delicate points, or grain growth", states a famous tool firm.

By eliminating loss of tools or injury to them, by increasing hardening room production, by improving the quality and increasing the productive life of tools—in these ways Certain Curtain Electric Furnaces very soon repay the money invested in them. Their unusual ability is due to the exclusive, patented Certain Curtain feature, which gives 100% control of furnace atmosphere. It enables you to vary the atmosphere for each type of steel and to maintain any desired atmosphere automatically.

Write for Bulletin "Precision Hardening"

C. I. HAYES, INC.

Makers of Electric Furnaces. Established 1905

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The VICKERS HARDNESS TESTING MACHINE

. . . . provides a proportional and absolute standard of hardness by the plastic indentation method. There is nothing empirical about it. It will test difficult specimens such as sheets under .007" thick; gear teeth on the working face; finished coil springs, etc., without damage. It is semi-direct reading and very fast . . . . In research work into the constitution and properties of nitrided steel cases, after a trial of other Hardness Testing Machines, this machine was selected as the most suitable, as besides the hardness, it indicates the friability of the case, which is a measure of its wearing qualities.

TERRITORIES OF UNITED STATES AGENTS FOR THE VICKERS HARDNESS TESTING MACHINE:

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MESSRS. WILLIAMS & WILSON, 84 Inspector Street, Montreal, P. Q.

NO STEEL OR ALLOY IS TOO HARD FOR TESTING ON THE VICKERS

STATEMENT OF OWNERSHIP, MANAGEMENT, CIRCULATION, ETC.,

Required by the act of Congress of August 24, 1912, of METAL PROGRESS, published monthly at Cleveland, Ohio, for October 1, 1932, State of Ohio, county of Cuyahoga, ss.

Before me, a notary public, in and for the State and county aforesaid, personally appeared Ray T. Bayless, who, having been duly sworn according to law, deposes and says that he is the assistant secretary of the American Society for Steel Treating, and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management, etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, postal laws and regulations, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, American Society for Steel Treating, 7016 Euclid Avenue, Cleveland, Ohio; Editor and Managing Editor, Ernest E. Thum, 7016 Euclid Avenue, Cleveland, Ohio; Business Manager, W. H. Eisenman, 7016 Euclid Avenue, Cleveland, Ohio.

2. That the owner is: The American Society for Steel Treating, 7016 Euclid Avenue, Cleveland, Ohio, which is an educational institution, the officers being: President, A. H. d'Arcambal; Vice-President, W. B. Coleman; Secretary, W. H. Eisenman; Treasurer, A. T. Clarage; Directors, J. M. Watson, B. F. Shepherd, C. F. Pascoe, H. D. McKinney and F. B. Drake. All above officers of the American Society for Steel Treating, address at 7016 Euclid Avenue, Cleveland, Ohio.

3. That the known bondholders, mortgagees and other security holders are: none.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

RAY T. BAYLESS, *Assistant Secretary of the American Society for Steel Treating.*

Sworn to and subscribed before me this 26th day of September, 1932.

ARTHUR T. WEHRLE (Seal)
Notary Public.
(My commission expires January, 1935)

2,316 MORE MANUFACTURERS OUT TO CAPTURE BUYERS'

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with a metal that stays forever bright . . .

2,316 more companies have sent initial orders for Allegheny Metal. They are going after customers' patronage with this everlastingly bright alloy — made into door knobs and kitchen sinks — straps for wrist watches and refrigerator parts — automobile accessories and chemical piping — boudoir lamps, dairy equipment, laundry machinery, eyeglass frames — almost everything made of metal is now, or soon will be, offered to customers in lustrous, ageless Allegheny Metal.

IT'S the modern metal. It is stronger than ordinary steel and as beautiful as freshly minted silver. It has no thin plating, no "protecting" coat of shellac — yet it stays forever bright without polishing.

Go out and look at the radiator of a two-year old Model A Ford and see how gleaming and bright Allegheny Metal stays, after years of hard exposure and temperature jumps from boiling to cold. If the radiator is dirty and mud-spattered, a damp cloth is all it needs to make it shiny bright again.

Orders coming into Allegheny offices this year promise that almost anything customers want to buy that is made of metal will soon be, or is already, offered by at least ONE manufacturer in this everlastingly bright Allegheny Metal.

Five years ago, when it first attracted nation-wide attention, we said, "No man can foretell how widely this bright metal will be used." At that time, it was getting its principal use in industry — in dairies, as the only alloy that will not taint milk — in chemical plants, as an acid-proof metal — in buildings as interior and exterior trim that must stand exposure without polishing. Since then it has been tested and tried in thousands of factories and more and more things are being made out of it for *everyone* to use.

Whatever it is that you are making, your customers are looking for a product that is made with Allegheny Metal — because they expect it to be a better value when they buy it and know it will be an unceasingly better value as they use it.

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1. Unsurpassed in corrosion resistance.
2. Can be drawn, stamped, machined, cast, forged.
3. Far stronger than mild steel.
4. Will take any finish from dull to mirror.
5. Is non-magnetic.
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7. Is readily annealed; may be welded and soldered.
8. Is produced in practically all commercial forms.
9. Immune to chemical reactions resulting from cooking and preparation of food . . . does not affect flavor, color or purity of any food.
10. Is a safe metal.

Manufactured pursuant to license from the Chemical Foundation, Inc., under basic patents No. 1,316,817 & 1,339,378

ALLEGHENY METAL

New literature for the asking

Four-Ton Coreless Induction Furnace—Ajax Electrothermic Co. A description of the largest Ajax-Northrup coreless induction furnace now in operation. Illustrated. Bulletin S-41.

Vanadium Steel Castings—Vanadium Corp. of America offers a technical booklet describing the properties developed by vanadium alloy steel castings. Jerome Strauss and Geo. L. Norris wrote the booklet. Bulletin S-27.

Springs—An elaborate 48-page catalog of springs, their design, manufacture, and engineering properties, has been prepared by Wickwire Spencer Steel Co. Bulletin S-37.

Scleroscopes—Shore Instrument & Mfg. Co. describes its Model D standard recording scleroscope in a recent bulletin which explains the theory and practice of hardness testing with this machine. Bulletin S-33.

Welding Electrodes—Numerous applications of inorganic flux coated welding electrodes are described in a booklet just published by Metal & Thermit Corp. which earlier this year introduced Murex heavy mineral coated electrodes. Bulletin S-64.

Heating and Cooling Wire—W. S. Rockwell Co. presents interesting technical information on improved methods of heating and cooling wire, with special reference to uniformity of structure and finish in a new folder. Bulletin RO-339.

Temperature Control—Valuable engineering information on this subject is contained in a well-illustrated 48-page booklet published by Foxboro Co. describing their line of temperature controllers. Bulletin S-21.

Slit Ultramicroscope—Bausch & Lomb Optical Co. has designed a new instrument which is especially adapted for the study of colloidal systems. An illustrated folder giving full details is available. Bulletin A-35.

Relays—General Electric Co. describes its high speed, directional distance, directional overcurrent and time induction types of relays in a recently published folder. Bulletin A-60.

Stainless Pipes and Tubes—National Tube Co. has published a large and attractive brochure covering its line of U S S stainless and heat resisting pipes and tubes. Valuable engineering data are presented. Bulletin A-92.

Deoxidizing Steel—Electro Metallurgical Sales Co. has published a new technical bulletin covering the use of silicon-manganese alloys for deoxidizing steel. Bulletin S-16.

Temperature Measurements—Leeds & Northrup Co. offers a 30-page booklet which discusses the application of their line of temperature measuring apparatus in power plants. Bulletin S-46.

Nickel Steel—International Nickel Co. is publishing a bi-monthly illustrated newspaper devoted exclusively to nickel alloy steels. Contains technical, semi-technical, and news articles dealing with the production, treatment, and uses of these steels as well as other special features. Bulletin JU-45.

Ferro-Carbon Titanium—An illustrated 111-page catalog technically describing this alloy and its use in steel for forgings, steel castings, rail steel, sheets, plates, etc., is offered by Titanium Alloy Mfg. Co. Bulletin J-90.

Wear and Lubricant Tester—Timken Roller Bearing Co. has prepared a description of a new machine for testing load carrying capacity of lubricants, measuring friction and wear of materials. Bulletin M-71.

"Carbonol Process for Carburizing Steels" is the title of the new 12-page bulletin published by the Hevi-Duty Electric Co. The bulletin describes the results and advantages of the Carbonol process of carburizing. Bulletin N-44.

Micro-Metallograph—E. Leitz, Inc. A precision instrument for making accurate photomicrographs without distortion and with absolute flatness of field is described. Bulletin M-47.

Heat and Corrosion Resistant Alloys—General Alloys Co. A new bulletin is available on chrome-nickel and straight chrome heat and corrosion resisting alloys. Bulletin D-17.

Peroxygen Compounds—A 24-page booklet issued by Roessler & Hasslacher Chemical Co. presents briefly the characteristics and uses of a number of peroxygen compounds. Bulletin M-29.

Welded Pipe—Republic Steel Corp. has prepared a booklet on its electric weld line pipe and casing. Manufacturing processes and performance data are presented. Bulletin AA-8.

Furnace Parts—Driver-Harris Co. has issued a bulletin featuring furnace parts made of their alloys. This bulletin gives data and advantages of Nichrome and Chromax heat resisting alloys in the form of furnace parts. Bulletin N-19.

Recuperators—Carborundum Co. The complete story of Carborundum Co. recuperators for industrial furnaces, describing the type and covering operating conditions. Bulletin F-57.

Chromel Couples—Hoskins Manufacturing Co. Bulletin contains technical data on pyrometer couples. Bulletin M-24.

Hy-Ten Alloy Steels—Wheelock, Lovejoy & Co., Inc. "Pertinent Points" folders covering physical properties, heat treatment and applications of all grades of Hy-Ten Special Steels. Bulletin D-22.

Furnaces for the Steel Industry—The Electric Furnace Co. have issued a four-page folder illustrating and listing several electric and fuel fired furnaces of various types they have installed in steel plants. Bulletin D-30.

Quenching—A new 80-page book, "Houghton on Quenching," containing over 30 charts and photomicrographs, has just been published by E. F. Houghton and Co. MM-38.

Globar Elements and Accessories—Globar Corp. A new leaflet containing a list of standard industrial type Globar electric heating elements and a coordinated list of terminal mountings and accessories. Bulletin N-25.

Circulating Oil Tempering Baths—A folder recently issued by American Electric Furnace Co. describes several models of their electrically heated oil tempering baths of the circulating type. Bulletin M-2.

Welded Construction—Bethlehem Steel Co. describes advantages of welded construction in building machinery parts from rolled steel parts and shapes. Results are said to be sturdier construction. Bulletin J-76.

Ammonia Dissociators—Ajax Electric Co. has a new bulletin describing the technical and economical advantages of producing hydrogen and nitrogen by dissociating anhydrous ammonia. Bulletin JU-83.

Ingot Molds—Gathmann Engineering Co. The subject of ingot molding is covered in a new book on this subject. Numerous illustrations of the effect of various methods of finishing and casting on the reliability of steel products are given. Bulletin D-13.

Rust Preventive—A recent publication of Dearborn Chemical Co. describes the well known rust preventive, No-Ox-Id, which is now offered as a paint foundation in the colors red, gray and black. Bulletin JU-36.

Machine Heat Treating—American Gas Furnace Co. A 16-page illustrated booklet giving information on the various types of conveyor heating machines available for heat treating on a production basis. Bulletin D-11.

Low Power Microscope—Carl Zeiss, Inc., has prepared a booklet describing a new low power binocular microscope, magnifying 4 to 31 diameters, which is valuable in examining fractures, etc. Bulletin MIK-464e.

Metal Progress, 7016 Euclid Ave., Cleveland.

Please have sent to me the following literature as described under "New Literature" in the October issue of METAL PROGRESS. (Please order by number.)

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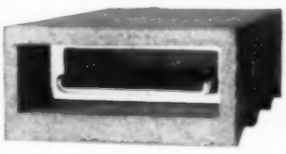
Name .....

Position .....

Firm .....

Address .....



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High Speed Steel

Improve Your Tools

Eliminate Scale . . . Decarburization and Reduction in Size

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SENTRY · DIAMOND · BLOCKS

Do you work skillfully to manufacture high speed steel tools that are of a definite size and finish, then burn away these tools to reduce their size and destroy their finish in hardening? . . . . Any reduction in size of tools during hardening is positive proof of this burning. . . . . When the time of heat treatment is reduced to minimize burning, maximum hardness may be sacrificed. . . . . Do timing variations affect the size of your tools and does an excessive period in the hardening furnace produce increased reductions in size or scale? Tools have been heated for one hour by the Sentry Diamond Block Method without burning away to produce any reduction in size, scale, decarburization, or other surface changes, and tools retain their fine finish under this severe test.

We invite you to confirm the above. . . . . Bulletins and prices on request.

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TAUNTON, MASSACHUSETTS

U. S. Patent 1,812,837
Other U. S. and Foreign Patents Pending

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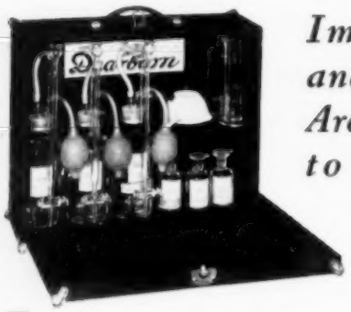

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Familiarize yourself with the full range of services Dearborn offers. They are the products of constant, purposeful research in the Dearborn Laboratories.

Dearborn Scientific Boiler Feed Water Treatment. . . . Dearborn methods have been based upon laboratory analysis of water supplies ever since we pioneered in the field of scientific water correction nearly fifty years ago. The Dearborn organization will continue to devote its best energies, as always, to finding a true analysis of the problem at hand and combating the trouble with the proper weapons.

Dearborn Water Testing Cabinet. . . . This wall or portable cabinet (illustrated) enables the engineer to test water samples, making all the tests required for efficient boiler operation.

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Water System Protection . . . Treatment provided to prevent corrosion or scale formation in circulating systems.

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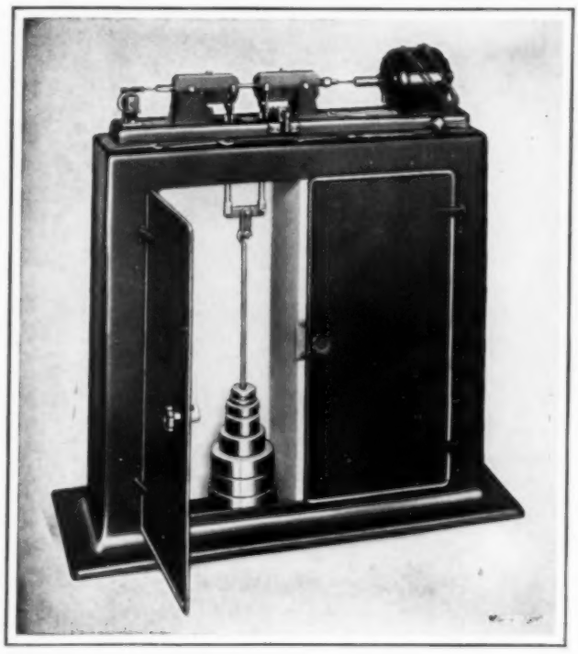
DEARBORN CHEMICAL COMPANY

concentrates

(Cont. from Page 80) consequently stresses are set up within the weld metal and the shell plate. These stresses can be relieved by heating uniformly to at least 1100° F., preferably 1200° or higher if this can be done without distortion. A large annealing furnace for this purpose is described by E. C. Chapman in *Fuels & Furnaces* for July. It is 64 ft. long and can hold any vessel up to 12 ft. diameter. Vessels are lowered into it by means of a crane and are supported by saddles properly aligned to prevent distortion. The furnace can be partitioned for any length of drum. It is fired by 75 gas burners, the hot gases entering through adjustable cracks for best distribution of heat.

OCCASIONS sometimes arise when it is necessary to redesign costly tools or dies—alterations which are impossible or very difficult with nitrided tools unless the surface can be materially softened. W. J. Merten has **SOFTENED NITRIDED PARTS** by immersing in a bath of fused sodium potassium nitrate (see these columns for January, 1932). H. H. Ashdown in *Machinery* for August says it can be done by heating them in aluminum powder up to its melting point (1220° F.). The entire case may be fused away by holding the parts in a molten aluminum bath for several minutes. "Denitriding" is a misnomer for this process since the nitride needles are not removed from the case but partially diffuse into the steel, although diffusion and decarburization are less than in the salt process. Although the hardness is never reduced to that of the original piece before nitriding, it has been reduced from 937 Vickers Brinell to as low as 420, and the piece is then readily machinable.

IN AN ATTEMPT to duplicate Herbert's reported **SUPERHARDENING** of metals by turning in a magnetic field, Y. Matuyama (*Science Reports*, Tohoku University, July) compared the changes in hardness with time in quenched duralumin (*a*) untreated, (*b*) turned in a magnetic field, and (*c*) after passage of an



THE R. R. MOORE
FATIGUE TESTING MACHINE

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A thoroughly practical and reliable machine for determining the life of metals. Adaptable to various shapes and sizes of specimens. • It has proven its value in the laboratories of scores of industrial corporations, government departments and universities.

WRITE FOR OUR PAMPHLET ON FATIGUE TESTING

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ELECTRIC FURNACES
(with atmospheric control)
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IN ALL THE MODERN TYPES AND SIZES
FOR EVERY INDUSTRIAL APPLICATION

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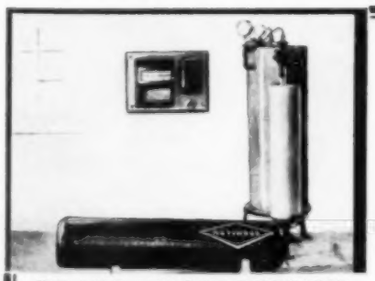

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ELECTRIC HEAT TREATING FURNACES

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Frankford Ave. & Allen St. PHILADELPHIA, PA.

electric current. The curves were parallel; fluctuations were within the 5% local variations demonstrated to exist. Armco iron, 0.60 and 0.70% carbon steel, high speed steel, and K.S. magnet steel were also given magnetic treatments and tested with Vickers hardness machine. Results were within observed local variations and indicated that magnetic treatment had no effective influence on hardness. K.S. magnet steel magnetized measured 52.1 with Herbert pendulum and 50.4 when demagnetized, but this difference was shown to be due to the magnetic forces exerted on iron and steel parts of the Herbert tester, which increased the period of the pendulum and consequently the indicated hardness.

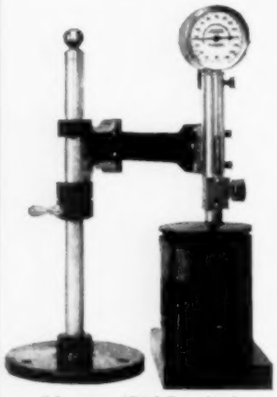
When Production Resumes

"Say Joe, did you get that cat and her kittens out of No. 2 mold?"
Courtesy of Collier's Weekly and Richard Decker

Accurate HARDNESS TESTS Made With The MONOTRON

Are NOT Limited To The METAL SERIES But Applied To All The KNOWN MATERIALS . . . But Why?

BECAUSE . . the Monotron is a perfected Hardness Indicator meeting all requirements in both the Laboratory and Shop, yielding qualitative and quantitive values. . . . The principle utilized is technically correct and the method employed is the ultimate method, which secures your investment in equipment of this kind. . . . Our now extensive list of satisfied users of this machine, of which we are proud, have found what we claim. . . . Why experiment with comparatively imperfect equipment when you can get what the other leading establishments are getting. . . . The Monotron has an unbroken scale extending from the softest to the hard and superhard metals obtained without adjustment or changing of points. This yields the correct comparative values. . . . The true Diamond Brinell at this time can only be measured with the Monotron. . . . It is wholly automatic, speedy and accurate and has dispensed with the microscope. . . . Setting to zero unnecessary. . . . . Tests the quantitative hardness of the thinnest case hardening, depth thereof and hardness of the core as separate factors. . . . Tests through scale and decarbonized surfaces. . . . Has the finest agreements with other like machines for specification purposes and can be fully rechecked independent of the maker in possible controversy. . . . . For additional information see our Bulletin M-3 and M-5, free upon request.



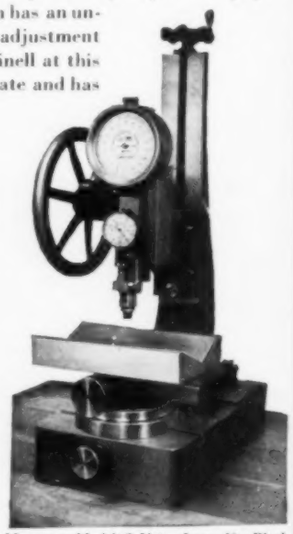
Scleroscope (Dial Recording) on Swing Arm

For a Good Single Dial Tester We Offer The
SCLEROSCOPE . . . latest improved

Quick, accurate, more popular than ever, it has the only simplified (Centigrade) scale which is understood and quoted the world over. The only tester that is 100% portable, and operative on work of unlimited size. Accurate conversions to Brinell.

Bulletins S No. 22 and S No. 30 mailed free

We also make the Durometer universally adopted as Standard for testing the hardness of rubber.



Monotron Model C Using Large Vee Block

The SHORE INSTRUMENT MFG. Co.
Van Wyck Ave. & Carll Street Jamaica, New York, N. Y.